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SCIENTIFIC DEPARTMENT

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TEA TANNIN AND CUP QUALITY

BY

C. R. HARLER

The relationship between the tannin in tea leaf and the cup quality of the tea made from that leaf is discussed below in three sections. The first deals with cup quality and indicates briefly how this is dependent on tea tannin. The second gives an account of some of the changes tea tannin can undergo *in vitro*, and also describes how tea tannin is affected when tea leaf ferments. This section is of a technical nature and deals largely with the failure of the hide power and Lœwenthal methods to estimate the mixture of tannin and tannin products which make up the total tannin in a tea infusion. In the third section is described the variation in the tannin content of leaf produced under different conditions of plucking, pruning and shade. This is followed by an account of the seasonal variation in the tannin of tea shoots and the effect this variation may have on the tea made.

Cup Quality.

Indian teas made in the rains sell largely on account of their cup quality, *i.e.*, colour, thickness, strength, "cream", briskness and pungency. These properties are due wholly or in part to tea tannin and tannin products, which latter are formed during the fermentation of tea leaf.

When the average India black tea is infused for 5 minutes, 25% to 30% of the solid matter in the leaf goes into solution, a great part of which consists of tea tannin and its products. Below is shown an average analysis of the chief products present in infusions of fine Assam teas. Such products as quercitrin, gallic acid and pigments, which occur in minute quantities, are not included. The tannin was estimated by the Lœwenthal method, further reference to which will be made later. This method gives values which fall short of the total tannin in the solution, a deficiency which is very roughly equal to the difference between the total

solids and the total of all the other substances likely to be present in appreciable quantities. This difference is included in the table as "tannin products" and is about equal to the "cream" precipitated when the tea first cools.

Soluble matter in a 5-minute tea infusion.

Total soluble solids	28.5%
Tannin	9.5%
Caffeine	3.5%
Other nitrogenous bodies	7.5%
Mineral matter	3.0%
Carbohydrates	2.0%
"Tannin products" (by difference) ...	3.0%
	28.5%

Tannin and tannin products are responsible for the colour of a black tea infusion. This is apparent from the following observations. Pure tea tannin gives a colourless solution. A fresh tea leaf infusion is very pale yellow in colour, owing to traces of yellow pigments extracted from the leaf. If tea leaf is crushed *in vacuo* the colour remains green, and the infusion is a pale yellow colour, the same as that of fresh leaf. If leaf is crushed in air and infused after a few seconds, a red solution is obtained, which colour must result from the formation of tannin oxidation products.

If undamaged tea leaf is heated above 90°F., either in air or vacuo, condensed tannin products are formed, the leaf turns red and, on infusion, gives a red solution. The redness in this case is due to tannin condensation products. In ordinary manufacture, however, this type of red substances can be avoided by working at temperatures well below 90°F.

Pure tea tannin has a bitter taste as has also a fresh tea leaf infusion. This bitterness is called "rawness" by tea tasters. Only after tea tannin has formed red products does its solution

assume an astringency which is known to tea tasters as pungency or briskness.

Thickness and strength are qualities associated with the concentration of solid matter in a tea infusion. The terms "thick" and "strong" connote pungency or briskness, and a concentrated liquor without either of these qualities is termed soft or flat. Since tea tannin and its products are responsible for both the pungency and briskness of a tea infusion, these are hence the most important factors in both thickness and strength.

The "cream" of tea is the precipitate which separates out as soon as an infusion cools. This precipitate consists mainly of tannin products but may also contain very small quantities of nitrogenous bodies.

The colour of the infused leaf whilst still wet is of interest. If this colour is bright red or golden, then the infusion is almost certainly good, but if the infused leaf is dull or greenish the infusion is usually poor.

The relationship between the colour of the infused leaf and the cup quality of the infusion may be explained as follows. The bright red or golden colour of the wet leaf is due to soluble red tannin products. If after a five-minute infusion, during which time tannin products have been going into solution, there is still enough of these substances left on the leaf to give a bright red colour, it may be expected that a large quantity of bright coloured tannin products will have entered solution. In other words the liquors will be good. If, on the other hand, the infusion leaf is dull, bright green or blackish green it may be concluded that mainly dull coloured tannin products, or small quantities of tannin products, have entered solution. In other words the liquors are dull or thin.

When any tea, good or poor, is extracted with boiling water for an hour or so, the spent leaf is blackish green in colour. This colour is due to the insoluble tannin in the leaf, the nature of which will be discussed below. The point of interest in the present con-

nection is that if the spent leaf from any tea is of the same colour, why should the leaf from a 5-minute infusion be an almost unfailing indication of the quality of the liquor. Why, for example, should it not be common to have dull infused leaf associated with bright liquors.

Theoretically this is possible. If we imagine the individual tea leaves to be caked with a layer of dried tea juice just thick enough to dissolve in a 5-minute infusion, we have a case for the bright, thick liquor and the dull infused leaf. In practice, however, the layer of tea juice is apparently never of even thickness and the nearest approach to the theoretical case is a good liquor with an unevenly coloured infused leaf.

The Changes in Tea Tannin during Fermentation.

Details of the work on the changes in tea tannin during fermentation are mainly of technical interest, although the results are of practical importance. The reader with no chemical knowledge is referred to the summary at the end of this section.

In the discussion which follows, a method for the separation of tannin from tea leaf is detailed. This is followed by an account of the oxidation, condensation and precipitation of tea tannin both *in vitro* and in the live leaf. Some observations concerning the estimation of tea tannin both by the Loewenthal and hide powder methods are made.

Preparation of tea tannin.

Tea tannin may be obtained from a fresh leaf infusion by the following method. The infusion is first extracted with benzene to remove gummy and resinous matter, then extracted with ether to remove gallic acid, which occurs in small quantities in tea leaf. The infusion is next extracted with ethyl acetate which dissolves most of the tea tannin. The ethyl acetate solution is dried over anhydrous sodium sulphate, then the tannin is precipitated as a white mass by chloroform, quickly filtered and dried *in vacuo*. A white powder is thus obtained which reddens in moist air.

Tannin thus prepared may be 85% pure, and one sample analysed to 94% purity. When estimated by the Loewenthal process (1), tea tannin requires a factor of 0.0416 per cc. normal permanganate used in oxidation, to convert the titration value to the weight of tannin obtained by the hide powder method.

When the tannin in fresh leaf infusion or withered leaf infusion is estimated by the Loewenthal method, the same conversion factor, 0.0416, serves.

Condensation and oxidation *in vitro*.

Tea tannin can be made to undergo various condensation and oxidation changes. By boiling with 5% sulphuric acid a series of condensation products is obtained with different degrees of solubility. Most of these substances are insoluble in water and, after about 36 hours boiling, a product which is insoluble in alkalies, alcohol and the commoner solvents is obtained. These products can be formed in the absence of air.

In alkaline solution and in the presence of air, tea tannin forms a series of oxidation products which finally are insoluble in water and have lost all their tannin value. All the oxidation products formed in alkaline solution are soluble in alkali and alcohol.

Many of the condensation and oxidation products of tea tannin are insoluble in water, and such substances are called phlobaphenes. It is not known whether the substances formed *in vitro* are formed during the manufacture of black tea, although oxidation products are formed in fermentation and condensation products are formed in the factory under certain conditions (2).

It is of interest to note that the white tea tannin obtained as described above gradually turns to a plastic red mass on standing in air for some days. The original white powder is distinctly bitter to taste but the plastic, red substance is strongly astringent.

(1) Procter's modification of Lowenthal's method. *U.S. Dept. Agr. Dept. Chem.* Washington (bull. No. 13, pt. 7, p. 80).

(2) For further details see "The Chemistry of Pharmacology of Tea", *Ind. Tea Assn., Quar. Jour.*, Calcutta, 1932 (pt. I, p. 24).

Similarly if a water solution of white tea tannin is evaporated to dryness on a water bath, a red, astringent substance is obtained.

Condensation in live leaf.

In the living tea leaf the tannin can undergo condensation. Thus, if leaf is heated it turns red, an effect which has been discussed before in this Journal (3). It is sufficient to state here the following facts. If tea leaf is heated to 160°F., the enzymes are inactivated. After such treatment no rapid changes in the tannin take place and the leaf can be kept for a long period without any appreciable alteration in colour or in tannin content. If, however, the leaf is heated to 150°F., it begins to redden in about 10 minutes. At lower temperatures the reddening appears after longer periods. These changes take place equally well *in vacuo* as in air. From the evidence it may be concluded that the change in tannin is one of condensation assisted by leaf enzymes. As a result of these changes what is known to the planter as "red leaf" is produced.

When red leaf is infused, the infusion is red and the infused leaf has not the bright, yellowish-green colour of infused fresh leaf, but is a dull blackish green, similar to that of spent tea. This colour may be due to the presence of the condensed tannin in the leaf. Extraction with alcohol fails to remove the colour, suggesting either that a very advanced form of condensation product has been made, or that the colour is due to something else, possibly a compound of leaf protein and condensed tannin.

When tea leaf turns red, tannin is lost. In one case the following was observed after the leaf had been allowed to redden in a basket for 18 hours at about 110°F. The tannin was estimated by the Loewenthal method.

Tannin in fresh leaf	...	21.13%
,, ,, red ,,	...	16.71%

Red leaf, when manufactured, makes poor tea with thin liquors and dull infusions. Red leaf may be avoided by keeping

(3) "The Withering of Tea Leaf", *Ind. Tea Assn., Quar. Jour.*, Calcutta, 1930 (pt. 4).

temperatures below 90°F., during withering, rolling and fermentation.

Oxidation of crushed leaf.

When tea leaf is crushed and the juice exposed to air it instantly turns red, oxygen is absorbed and the soluble tannin content of the leaf decreases. If leaf is crushed *in vacuo* it remains green and there is no change in the tannin content. The reddening is due to the oxidation of tea tannin by an enzyme (oxidase) in the leaf. Leaf which has been killed by heating to 160°F., can be rolled without any appreciable change in colour or tannin content.

The rate of oxygen absorption is rapid when the leaf is first crushed, but slows off after 3 or 4 hours. When the amount of oxygen absorbed is plotted against time, a curve which tails off, typical of oxidase reactions, is obtained. As the oxygen absorption proceeds the soluble tannin in the leaf decreases. Details of this aspect of manufacture carried out within recent years have been reported from this Department and by Ceylon workers (4). The subject will not be again treated here, but an attempt will be made to indicate the manner in which tea tannin becomes insoluble during the fermentation of tea leaf. Before doing this, something must be said on the subject of the estimation of tea tannin and its soluble products.

Hide powder and Loewenthal methods.

There is no difference between the tannin content of fresh and withered leaf as estimated by the Loewenthal or hide powder processes.

As soon as fermentation begins and oxidised tannin bodies are formed, the Loewenthal process for estimating the mixture of tea tannin and tannin products gives a lower value, using the conversion factor of 0.0416, than the hide powder method. When a fresh conversion factor is calculated it is found that each infusion requires its own factor to suit the individual mixture of tannin

(4) Report by the Chief Scientific Officer for 1930, Indian Tea Assn., Calcutta, 1931 (p. 7).

The Research Institute of Ceylon, Annual Report for 1927, Kandy, 1928 (p. 22).

and tannin products. Conversion factors varying between 0.055 and 0.070 have been found necessary to make the Loewenthal value agree with the hide powder figure.

The hide powder method for estimating the total tannin in tea infusions also fails to give a true value with most tea infusions for the following reasons. In this estimation it is necessary that the tannin solution shall be clear to transmitted and reflected light, and shall contain between 0.375 and 0.425 gms. tannin per 100 cc. (5). The normal tea infusion is not clear on cooling and after filtering to clearness, the resultant solution generally contains usually only about 0.25 gms. tannin per 100 cc.

The effect of dilution below the requisite strength, on the tannin value of a solution as estimated by hide powder is shown in the following cases dealing with the both fresh leaf and tea infusions. a fresh leaf extraction containing 0.406 gms. tannin per 100 cc. by the hide powder method was diluted to contain 0.203 gms. On estimation by the same method the weaker solution gave a result showing 0.220 gms. tannin. Again, a tea infusion containing 0.430 gms., tannin by the hide powder method, on dilution to half strength gave a tannin value by the same method of 0.250 gms. per 100 cc. instead of 0.215 gms. It thus appears that dilution below the standard strength required for the hide powder method gives high values for tea leaf and tea infusions.

Thus whilst the Loewenthal method gives low values lower than the hide powder method for tea infusions, the latter method gives values which are generally too high. The true value is probably somewhere between the two.

Although other workers have realised the short-comings of both the Loewenthal and hide powder methods for estimating the total tannin in tea (as is shown by their abandonment of both methods), the failure of both methods has not been put on record so far as the writer is aware. On this account the above facts are published.

(5) This is the standard adopted by the American Leather Chemists Assn. For details refer to *J. Am. Leather Chem. Assn.*, 1921 (vol. 16, 0, 113).

The precipitation of tea tannin by proteins.

Fresh leaf contains about 20% tannin, and finished black tea a total of about 11%. This latter value, which is approximate only, is the mean between that given by the Loewenthal estimation using a factor of 0.0416, and that given by the hide powder method. The "cream" in a tea infusion, which is best separated by means of a centrifuge, accounts for about 3% tannin, bringing the total tannin and tannin products up to about 14%.

It is thus still necessary to account for about 6% of the tannin, which remains insoluble in the leaf. This is present either as insoluble condensation or oxidation products, *i.e.*, phlobaphenes, or combined with leaf proteins, in the form of a leather-like substance.

Of the phlobaphenes formed *in vitro* only the condensed product obtained by boiling tea tannin with 5% sulphuric acid for 36 hours is insoluble in all the commoner solvents, including alcohol and alkalies.

When tea is exhaustively extracted with water, the residue is blackish green in colour. When this spent tea is extracted with alcohol, a green solution, so coloured by chlorophyll, is obtained and no coloured tannin body is apparently present. When spent tea is extracted with alkali a deep red solution is obtained which gives a bulky precipitate on acidification. The leaf residue after this treatment is a yellow-grey mass.

These reactions suggest that the tannin is not present in the spent leaf as phlobaphenes and render likely the assumption of a compound with proteins. Such a compound would be decomposed by alkalies, and the liberated tannin oxidised in the alkaline solution to a phlobaphene.

As previously mentioned, when tea leaf is crushed *in vacuo* there is no loss of soluble tannin. It must hence be assumed that only after oxidation does tea tannin develop the power to precipitate leaf proteins. This is in line with the fact that unchanged tea tannin does not precipitate gelatine from dilute solutions.

The pure proteins within the leaf, which presumably are capable of precipitating oxidised tea tannin, show a nitrogen content of about 2.9% of the total dry matter on leaf plucked in Assam. This indicates about 17% pure proteins in the dry matter of the leaf.

Summary.

The important points in the above discussion may be summarised as follows.

1. Pure tea tannin may be condensed and oxidised in the laboratory to give red brown insoluble substances. It is not known whether the same substances are formed in normal tea manufacture.

2. When tea leaf is heated above 90°F., for a few hours "red leaf" results owing to the formation of red, insoluble tannin products. Tea made from such leaf is thin with dull infusions. The formation of red leaf can be avoided by keeping the leaf cool in the baskets and by withering and fermenting at temperatures well below 90°F.

3. When tea leaf is crushed in air, oxygen is absorbed and the tannin oxidised. Some of the oxidised substances are probably precipitated by proteins within the leaf and thus rendered insoluble. After this precipitation has taken place any oxidised tannin left enters the infusion to give cup qualities.

4. Neither the Loewenthal nor hide powder methods satisfactorily estimate the mixture of tea tannin and tannin products which make cup quality in a tea infusion.

Variation in the Tannin Content of Tea Leaf.

Having indicated that cup quality is dependent on the tannin and tannin products in the infusion, the importance of the amount

of tea tannin in the original leaf will be appreciated. It may be anticipated that leaf rich in tannin will tend to give tea with good cup quality.

An analysis of good leaf and poor leaf reveals how great may be the difference in tannin between leaf samples. The table below shows the tannin, caffeine and water-soluble content of soft, succulent young leaf plucked in Assam, and of poor leaf which was harder and dryer being plucked in an unfavourable part of the season, but still young. The samples were extracted for one hour with boiling water. The percentages are calculated on the dry matter.

	Good leaf.	*Poor leaf.*
Tannin ...	25%	15%
Caffeine ...	4%	2%
Soluble solids ...	49%	35%

There is a wide variation in the tannin content of various parts of the shoot, as shown in the next table.

Bud ...	29.8% tannin.
First leaf ...	29.9% ,,
Second ,, ...	21.3% ,,
Third ,, ...	17.8% ,,
Fourth ,, ...	14.5% ,,
Upper Stalk ...	11.7% ,,
Lower ,, ...	6.4% ,,

This illustrates how the fineness of the leaf may influence cup quality. In India, Ceylon and Java, a shoot of two leaves and a bud contains from 17% to 23% tannin, although values wide of these can be obtained.

Quality tea can be made only from fine leaf, and whilst the economics of fine and coarse plucking is beyond the scope of the present discussion, it is useful here to state what is considered a fine pluck. A sample of fine leaf plucked in the height of the season should be composed of shoots of about the following order.

10% one leaf and a bud (large).
65% two leaves and a bud.
15% soft single *banjhi*.
5% three leaves and a bud (small).
5% soft double *banjhi*.

If the bushes are plucked every six or seven days and everything taken, this standard can be achieved. In the early part of the season the percentage of *bhanjis* should be much smaller.

Coarse leaf is not only poorer in tannin than fine leaf but is tougher on account of the higher content of the crude fibre and cellulose. This makes difficult the expression of juice in rolling which, in turn, reduces the amount of oxidation and tends to produce thin liquors and poor cup quality. The variation in crude fibre and cellulose in the shoot is shown in the next table.

	Crude fibre.	*Cellulose.*
Bud	... 12.8%	6.5%
First leaf	... 15.0%	8.0%
Second ,,	... 17.0%	9.4%
Green stalk	... 25.3%	14.6%

The type of plucking influences the amount of tannin in the leaf. *Banjhi* (dormant) shoots or leaf plucked from seed bushes contains much less tannin than leaf from normal plucking bushes. Thus in the month of July the following figures were obtained in Assam.

Normal plucking shoots	...	20.13% tannin.
Shoots from tea seed trees	...	16.14% ,,
Banjhi (dormant) shoots	...	13.06% ,,

The length of the plucking has a very definite influence on the tannin content of the shoot. In one season in Assam it was observed that bushes pruned to 9″ and plucked at 36″ gave leaf with an average tannin content of 22.7%. Similar tea, pruned at 30″ and plucked at 36″, gave leaf with an average tannin content of 24.2%. It is generally recognised amongst planters that

close plucking gives teas with better quality than long plucking, provided the leaf is equally fine in both cases.

There is no appreciable variation in the tannin content of leaf from bushes of different variety grown under the same conditions. The following figures, recorded in June on fine leaf grown in Assam, are all well within the variation due to sampling error.

Shoots of Burma variety	...	21.09% tannin.
,, ,, Assam ,,	...	20.89% ,,
,, ,, China ,,	...	21.15% ,,

In Japan, the China variety of bush yields shoots containing only about 15% tannin (6). In the Caucasus somewhat higher values have been recorded for leaf from China bushes, but values still below those in India (7).

In North East India a general seasonal change in the tannin content of the shoot has been observed, a change which will later be examined in detail. At the beginning of the season (March and April) the tannin content is low in tippings from pruned tea. From May to the end of the season it is higher although it shows considerable fluctuation. In 1932, the following were the tannin contents observed on the Kalline plots of the Tocklai Clearance in the early part of the season.

March 25th.	...	15.50% tannin.
April 5th.	...	20.86% ,,
,, 19th.	...	25.17% ,,
,, 26th.	...	23.01% ,,
May 4th.	...	23.54% ,,
,, 11th.	...	22.64% ,,
,, 18th.	...	20.97% ,,
,, 25th.	...	21.13% ,,

During the full season in Assam the tannin fluctuates between about 18% and 22%.

(6) "Tea in Japan" *Ind. Tea Assn., Quar. Jour.*, Calcutta 1924 (pt. I, p. 39).
(7) J. Galy-Carles, *Rev. App. Bot. Agr. Cal.*, Paris, 1928 (Bull. 86, p. 683).

In Japan (8) and the Caucasus (7), where the flush ceases in the cold weather, the early pluckings are poorer in tannin than the later ones. In Java, where there is no close season, and the bushes are plucked the whole year and usually pruned every other year, the flushes following the pruning are poorer in tannin than those plucked in the full season (9). In Ceylon it has been recorded on a high-grown garden that five months from pruning the tannin content of the shoot was 14.4%, sixteen months from pruning it was 18.7% and thirty-four months from pruning it was 17.3% (10).

In Assam, the leaf from unpruned bushes has a much higher tannin content at the beginning of the season than that from pruned tea. Thus in March, 1932, leaf from the Kalline and China areas of the Tocklai Clearance, which were half pruned and half unpruned, gave the following tannin percentages.

China	bushes	pruned	...	18.27% tannin in shoots.
,,	,,	unpruned	...	20.14% ,, ,, ,,
Kalline	,,	pruned	...	15.50% ,, ,, ,,
,,	,,	unpruned	...	21.27% ,, ,, ,,

The earlier pluckings from unpruned bushes give better teas than those taken from pruned areas during the earliest part of the season.

In April of 1932, the leaf from a certain area on a garden in the Jorhat district which had been partly pruned in January and partly in the previous July, was examined for tannin with the following results.

July	pruned	bushes,	plucked in April	23.87% tannin.
January	,,	,,	,,	21.29% ,,

The tea made from the July pruned area was markedly better than that from the January pruned area.

(8) The Chemistry of Green Tea, *Tea Experimental Station Publication* Kanaya, Japan, 1923.

(9) J. J. B. Deuss, *Archief Theeculture*, Batavia, 1928 (vol. I, pt. 4, p., 123).

(10) M. Kelway Bamber, *Ceylon Tea Soils and their effect on the quality Tea* Colombo. 1900.

Shade affects the quality of tea and in Assam it has been found that heavy shade has an adverse influence.

In the Bishnath district, between 1923 and 1925, experiments were carried out to observe the influence of shade on both the crop and the quality of the tea. The former influence is fairly well appreciated, and reasonably light shade may put as much as 240 lbs. tea per acre on the crop. On the subject of quality, however, less definite information is available. In the experiment under discussion it was found that in the rains the unshaded area gave the best quality teas, followed closely by the area lightly shaded, *i.e.*, trees planted 60 × 30 ft. During the second flush the best teas were made from the lightly shaded area. The heavily shaded area, trees planted 30 × 30 ft. gave the poorest teas throughout the season. Details of the experiment are given in a previous number of our Journal (11).

Bamber, in Ceylon, showed that the leaves of a tea bush exposed to the sun contained more tannin than inner leaves not so exposed (10). Hope, in Assam, showed that bushes shaded either by grass or trees gave leaf with a smaller tannin content than that plucked from unshaded bushes (12).

In the Uji district of Japan it is customary to shade the bushes under dense grass shade for about three weeks before the first flush which produces the fine Gyo Kuro tea. This shade reduces the anthocyan content of the leaf and thus improves quality. The anthocyans are pigments which give a faintly bitter taste to the infusion. It has also been observed that such shading reduces the tannin content of the leaf in Japan by as much as 3% (8).

All observations go to show that anything which reduces the tannin content of the shoot, *e.g.*, coarse leaf, long plucking, too much shade, reduces the quality of the tea.

It is now proposed to examine more closely the seasonal variation of the tannin in shoot. During the season 1928, the pluck-

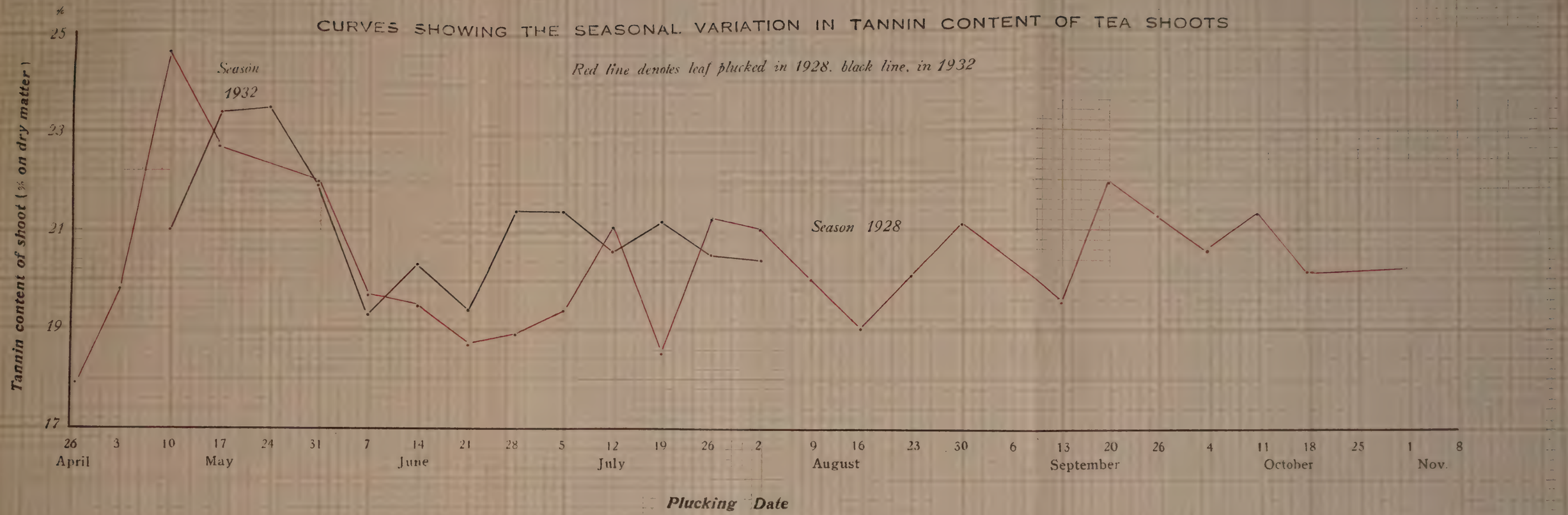
(11) *Quar. Jour. Ind. Tea Assn.*, Calcutta 1926 (pt. 2, p. 89).

(12) G. D. Hope, *Experiments on the Quality of Tea, Ind. Tea Assn.*, Calcutta, 1910.

ings from certain plots at Borbhetta were analysed weekly for tannin. The leaf was plucked from five separate plots and analysed separately. The average weekly figures are shown in the table below and are plotted on the accompanying graph. All the leaf plucked was fine and, as strictly as possible, two leaves and a bud.

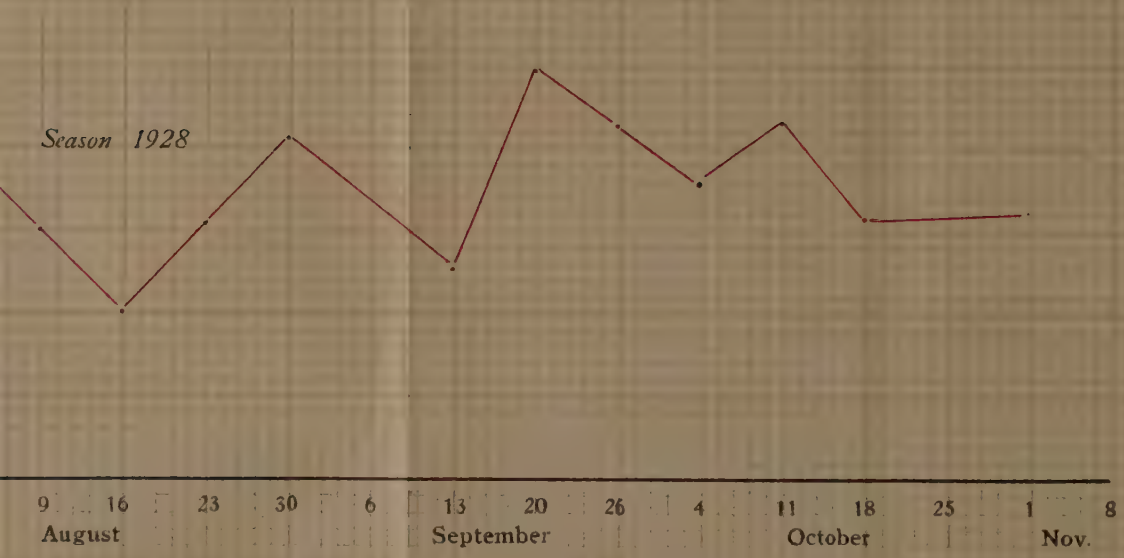
Tannin variation in shoots plucked in 1928.

Date of plucking 1932.	*Tannin content* %
April 26th.	17.91
May 3rd.	19.94
,, 10th.	24.59
,, 17th.	22.72
,, 31st.	22.26
June 7th.	19.73
,, 14th.	19.48
,, 21st.	18.64
,, 28th.	18.95
July 5th.	19.15
,, 12th.	21.12
,, 19th.	18.01
,, 26th.	21.18
August 2nd.	21.05
,, 9th.	18.98
,, 16th.	18.98
,, 23rd.	20.03
,, 30th.	21.14
Sept. 13th.	19.45
,, 20th.	21.88
,, 27th.	21.26
October 4th.	20.61
,, 11th.	21.31
,, 18th.	20.19
November 1st.	20.19
,, 8th.	17.89


CURVES SHOWING THE SEASONAL VARIATION IN TANNIN CONTENT OF TEA SHOOTS
Red line denotes leaf plucked in 1928. black line, in 1932
%
25
23
21
19
17
Tannin content of shoot (% on dry matter)
Season 1932
Season 1928
26 3 10 17 24 31 7 14 21 28 5 12 19 26 2 9 16 23 30 6 13 20 26 4 11 18 25 1 8
April May June July August September October Nov.
Plucking Date

N IN TANNIN CONTENT OF TEA SHOOTS

1928. black line, in 1932



June	1st.	21.98
,,	8th.	19.32
,,	15th.	20.35
,,	22nd.	19.43
,,	29th.	21.40
July	6th.	21.40
,,	13th.	20.59
,,	20th.	21.41
,,	27th.	20.57
August	3rd.	20.44

These tannin values are also plotted on the accompanying graph and are shown as a black line against the red denoting the 1928 variation. Over the first part of the 1932, season the colours made by gardens near Tocklai varied very closely with the tannin content shown on the curve. During the period about May 18th. to 25th. the infused leaf was copper coloured. After this period the colour fell off steadily till June 7th. Colours improved slightly about June 21st., although the tannin actually decreased somewhat. This improvement was probably due to a decrease in the leaf proteins at this time. From June 21st. the colours improved and were very good about June 28th. to July 5th., after which they became dull again as the tannin decreased.

So far we have found no obvious correlation between the crop curve and the tannin change, neither between certain climatic conditions, *i.e.*, sunshine, rainfall and temperature, and the seasonal variation in tannin. The tannin in the shoot varies with the origin of the shoot. Thus a primary shoot plucked just before it goes *banjhi* is poor in tannin. The earliest tippings in the season are largely composed of such shoots. A primary shoot plucked from growth which has gone *banjhi* and subsequently come away again has a very high tannin content if plucked just over the new *janam*. Most of the leaf plucked about May 18th. to 28th. in the present season (1932) consisted of shoots of this type.

The tannin in the shoot is affected by certain manuring and it has been observed that a heavy dose of nitrogen of 120 lbs. per

acre depresses the tannin content. Normal doses, *i.e.*, 30 to 40 lbs. nitrogen per acre, have no such marked effect and may even give leaf richer in tannin than that obtained from unmanured plots. It is possible that potash and phosphatic manures also influence the tannin content of the leaf when applied in suitable doses. The effect of manures on the tannin in tea leaf is still under study.

The causes of the seasonal tannin variation in tea leaf are thus yet to be determined, but when they are known and understood it is unlikely that we shall be able to control them in practice.

It is common experience that the colours of the infusion improve and deteriorate periodically during the season. The tannin curves offer an explanation of these changes, and whilst it is possible that other factors are involved, tannin is probably the controlling one.

Regarding other factors which may influence cup quality, it is likely that the protein content of the leaf is important since proteins can render insoluble oxidised tannin. The seasonal variation in the leaf proteins is now under study in conjunction with tannin variation.

PRUNING EXPERIMENTS

BY

H. R. COOPER

The results of experiments to the end of 1931, have been summarised in the Annual Reports of the Chief Scientific Officer, and some of these were used in the discussion of possible economies through pruning, published in Quarterly Journal, 1931, part III. The more important results have been tried in garden practice on a number of gardens.

A fuller presentation of the evidence, accompanied by further evidence, mainly relative to the effects of seasonal differences in the same district and of climatic differences between different districts, is now thought desirable. The fresh discussion is undertaken in the hope that the results may be accepted more widely and with greater confidence, and in order to suggest modifications of normal practice which may prove useful under conditions of shortage of labour in the rush season, particularly where the production of good teas by fine plucking is aimed at.

The crop curve.

In spite of big differences due to climate, the tea crop comes at much the same times of year all over North East India. The seasonal nature of the crop is best shown by plotting the weights of weekly pluckings from any particular area against the date of plucking. Examples of such "crop curves" are shown facing page 132.

Tea in North-East India, however pruned or manured, slows up very rapidly in growth after about the middle of October. By December very little can be obtained; though rather more is obtained, for example, in the Surma Valley, where higher temperatures and longer periods of daylight are maintained, than in Upper Assam. During January and February the leaf grown is negligible. The possi-

bility of increasing this cold weather crop is one of the points investigated. About the middle of March spring growth starts vigorously, and, from unpruned tea big crops may be taken at the end of March and early April, if spring rain is at all favourable. With tea pruned in the previous cold weather this first flush is used to bring the new shoots up to the plucking level, and the "first flush" crop taken consists of an almost negligible quantity of tippings of very poor quality.

The first flush is followed by a lull in the rate of growth (not always noticeable in the small crop from pruned tea, but usually marked in the case of unpruned tea) until the "second flush" begins to come through about the middle of May, and big crops again are taken in very late May and early June. Then follows another lull, until the third flush yields well from about mid-July. After that crop is fairly steady at a high level until the tea begins to close up for the season.

Lulls and rushes during the period of high crop starting in July are mainly from climatic influences, and are not generally very marked, though in some seasons (*e.g.*, 1931) crops do fluctuate greatly even in the rains.

From tea pruned annually in the cold weather, (as is the most general practice) it is common that about 75% of the season's crop is grown (though it cannot always be plucked) in about 16 weeks between early July and late October. This concentration of the crop is a great practical disadvantage, particularly as the rice-planting seasons and the tea harvest seasons coincide during July and August, and perhaps September; and, from the point of view of the labourer, the profit from plucking tea is often a subsidiary consideration to the profit and interest of growing his own rice.

Few gardens can afford to maintain during the other eight months of the year, a labour force adequate for strict plucking and reasonable cultivation during the four months of big crop. The result is that the planter is commonly faced with the alternatives

of taking very coarse leaf of poor quality at long intervals, or of failing to harvest a large part of the crop grown.

The experiments here described have been successful in indicating methods of increasing crop from March to June, while the examination of methods of reducing losses in the rains have practical value. At present, attempts to get "cold-weather" crop appear hopeless, while very little help can be given in increasing autumnal crops.

"Skiffing" in the Rains.

When it becomes clear that the available labour is incapable of plucking the whole garden at sufficiently close intervals, it has become customary on many gardens, to "skiff" off the ready leaf either with special knives or with bamboo laths with sharp edges. This matter will be discussed first.

The skiffing, of course, loses the crop then ready ; but bushes remain in pluckable condition for the time when labour is again available instead of "running away". The skiffing of course requires labour; but even where such labour has to be withdrawn from the plucking force, only about one third as much labour is necessary as would be required for plucking the same area, while in many gardens labour unable to pluck can be used for the work.

The following points were investigated :—

(1) Effect of time interval between skiffing and previous plucking.

(2) Effect of heavy against light skiffing, and of skiffing twice at short intervals against once after twice the interval.

(3) Effect of skiffing against "plucking with breaking back" of tea unplucked for several weeks.

(4) Effect of leaving unplucked altogether until pruned early, as against skiffing. This investigation will not be complete until the close of the current season, but the effect on early crop is quoted.

In each case the experiments were made on areas made up of three (sometimes four) small plots chosen that yields both in previous seasons and in 1931 up to the time of starting the experiment had been practically the same for each set of plots to be compared.

For example in the first set of trials recorded the following had been the previous yields.

Yields in lbs. green leaf per set of 3 plots of 84 bushes per plot.

	1930 (full season).	1931 to August 1st.
Set. 1	... 342	... 140
,, 2	... 345	... 146
,, 3	... 345	... 145
,, 4	... 348	... 137
,, 5	... 347	... 140

I. *Effect of time interval between skiffing and previous plucking.*

The results may be tabulated for convenience as weekly yields in mds. green leaf per acre.

Skiffing in Rains.

TABLE I.

Effect of skiffing in rains on crop (in mds. green leaf per acre).

Regularly plucked.			Skiffed after 2 weeks unplucked.			Skiffed after 3 weeks unplucked.			Skiffed after 4 weeks unplucked.			Skiffed after 5 weeks unplucked.		
August	8th	2·20	unplucked	} 3·93		unplucked	} 5·68		unplucked	} 7·48		unplucked	} 10·13	
,,	15th	1·73	skiffed	} loss		unplucked	} loss		unplucked	} loss		unplucked	} loss	
,,	22nd	1·75	1·61	} 1·90		skiffed			skiffed			unplucked		
,,	29th	1·80	1·42	} loss		1·25	} 5·16		0·49	} 8·66		skiffed		
September	5th	2·65	2·28			1·25			0·37			0·21	} 8·73	
,,	12th	2·98	1·97	} 1·81		0·95	} loss		0·26	} loss		0·13		
,,	19th	2·55	3·96			1·37			0·77			0·06	} loss	
,,	26th	2·37	2·77	} gain		3·81	} 2·28		4·73	} 4·81		0·44		
October	3rd	1·77	1·73	} 0·39		2·97	} gain		3·41	} gain		3·74	} 4·38	
,,	10th	1·56	1·49	} loss		1·33	} 1·57		1·60	} 2·79		4·25	} gain	
,,	17th	2 05	1·77			0·93	} loss		0·91	} loss		1·93	} 3·13	
,,	24th	1·83	1·99	} 0·12		1·61			0·88			0·67	} loss	
,,	31st	2·30	2·47			2·09	} 0·38		1·85	} 0·57		0·50		
November	7th	2·10	1·86	} gain		2·28			1·72			0·93	} 0·38	
,,	14th	1·05	1·06			1·25	} gain		0·44	} gain		0·53	} gain	
,,	21st	0·30	0·34			0·39			0·58			0·84		
,,	28th	0·57	0·55			0·48								
			total loss = 4·29 mds. or about 2 weeks crop. Should be plucked weekly from 7 days after skiffing.			total loss = 9·75 mds. or about 4 weeks crop. Should be plucked weekly from 7 days after skiffing.			total loss = 13·55 mds. or about 6 weeks crop. Better plucked 14 and 28 days after skiffing. Must be plucked 28 days after skiffing before the bumper crop of the 35th day after skiffing.			total loss = 17·23 mds. or about 8 weeks crop. Should be plucked 28 days after skiffing, before the bumper crop of 35th day after skiffing.		

It will be observed that in each case, the skiffing is followed by four weeks of reduced crop, the losses during the four weeks being the greater, according as the interval between skiffing and the previous plucking was greater. Also, in each case, this four weeks of reduced crop is followed by two weeks of crop greater than that produced from regularly plucked tea. This gain is the greater according as the interval between skiffing and previous plucking was greater. The big gains of these two weeks, are again followed by three weeks of loss compared to tea regularly plucked, and this loss is the greater according as the interval between skiffing and previous plucking was greater. After nine weeks from skiffing, the skiffed tea yields a very little more than the tea which has been regularly plucked.

If tea is skiffed, instead of being plucked in the usual way, one week after the last plucking, it may be assumed that only that week's crop is lost. If left for two weeks and then skiffed, the total loss is about 2 weeks' crop.

For every week left unplucked after two weeks, the loss of crop is about equal to two weeks' crop.

It is advised therefore that tea should be left unplucked, before skiffing, for not more than 14 days. Skiffing after 14 days unplucked is considered better than skiffing weekly, because it entails no more loss of crop and only half the labour is required for the skiffing.

If tea, after skiffing once, still cannot be plucked for want of labour, it should be skiffed again after another fortnight, as is shown in the following experiment, where also the effect of heavy as against light skiffing was tried.

II. *Effect of skiffing twice at fortnightly intervals, as against that of skiffing lightly and heavily after leaving unplucked for four weeks.*

TABLE II.

Crop in mds. green leaf per acre.

Regularly plucked.	Skiffed twice.	Skiffed once lightly.	Skiffed once heavily.
August 8th	unplucked	unplucked	unplucked
,, 15th	skiffed	,,	,,
,, 22nd	unplucked	,,	,,
,, 29th	skiffed	skiffed lightly	skiffed heavily
September 5th	1·90	0·80	0·45
,, 12th	1·29	0·45 loss	0·47 loss
,, 19th	1·83	0·18 4·38	0·20 4·52
,, 26th	1·11	0·32	0·49
October 3rd	1·31	2·05 gain	3·20 gain
,, 10th	1·24	2·46 1·96	2·49 3·14
,, 17th	1·50	1·35	1·17
,, 24th	1·91	1·01 loss 1·88	0·79 loss 2·22
,, 31st	1·54	0·71	0·77
November 7th	1·45	1·43	1·67
,, 14th	0·87	0 96 gain	0·97 gain
,, 21st	0·27	0 37 0·41	0·27 0·66
,, 28th	0·45	0·69	0·79
	16 67	12·76	13·73

Unfortunately the area available was not large enough to enable a fourth area to be plucked regularly, for comparison.

It is clear that there is much less loss of crop from skiffing twice at short intervals than from skiffing once after a long interval. From the previous experiment it is probable that the tea skiffed twice lost just about the crop of the four weeks during which it was not plucked, while the tea skiffed once after the four-week interval from last plucking, lost about an extra two weeks crop.

When skiffing after a long interval it makes little difference to total crop whether the skiffing is light or heavy, and therefore

the skiffing might as well be light, since the work is much cheaper and more rapid. The "heavily" skiffed tea was cut just above the level at which it was last plucked, removing stout shoots, a few of which had reddened at the base.

The "light" skiffing was about one big leaf higher (roughly 2″) where shoots were all green and still soft.

The gain obtained from heavy as against light skiffing is all in the rush of leaf obtained in the fifth and sixth weeks after skiffing. This may be looked upon as "forced" growth probably of poor quality.

When tea is skiffed after being unplucked for a long period, it is therefore considered preferable to make the skiffing a light one. Still lighter skiffing removing only a few leaves was not tried : the probability is that by such light skiffing the loss in crop over the following four weeks would be less, but that the tea would tend to shut up earlier. It is probable that the later in the season the skiffing is performed, the lighter it should be.

III. *Effect of Skiffing against.* (1) *Plucking with Breaking Back and against.* (2) *Leaving Unplucked altogether and Pruning Early.*

When tea has been unplucked for some weeks, it has been suggested that when labour is again available it would be better to take the leaf on the bushes, instead of skiffing and throwing it away, the pluckers being instructed to break back the long shoots as far as they can on green wood so as to keep bushes at a reasonably low level.

It is possible also that bushes may be so improved in vigour by not being plucked, that it might pay, in crop in the following season, simply to leave bushes unplucked when labour for plucking is short; particularly if the unplucked bushes are pruned early. Unfortunately only some very young tea (planted 1926) was available for experiment on these points in 1931, but the results may be taken as indicative of what may be expected from mature tea.

The pruning of the tea left unplucked was done in early October, because this is about the earliest that labour for the purpose may be expected to be available for the purpose, and because other experiments (to be quoted) indicate that this is about the pruning-time likely to give maximum crop during the following season, and likely also to give the biggest crop of valuable second flush tea.

The pruning in October was not a skiff, but a real pruning leaving about 1″ of one-year-old wood, with cleaning out—exactly the same pruning as was performed on the rest of the tea in the following December.

TABLE III.

Yields in lbs. and ozs. green leaf per 260 bushes.

TREATMENT.

Date.	I Plucked regularly.	II Broken back after 4 weeks unplucked.	III Skiffed after 4 weeks unplucked.	IV Pruned early.
11th. August ...	7-5	unplucked	unplucked	unplucked
18th. ,, ...	9-6	-do-	-do-	-do-
25th. ,, ...	7-14	-do-	-do-	-do-
1st. September	10-2	16- 0	skiffed.	-do-
8th. ,, ...	10-2	5- 15	3- 14	-do-
15th. ,, ...	13-3	3- 10	3- 13	-do-
23rd. ,, ...	13-2	1- 3	1- 12	-do-
29th. ,, ...	12-14	3- 2	4- 5	-do-
6th. October ...	11-0	16- 3	23- 0	-do-
13th. ,, ...	7-14	13- 2	13- 1	pruned
23rd. ,, ...	19-6	14- 5	14- 11	unplucked
27th. ,, ...	6-12	5- 7	4- 13	-do-
3rd. November	10-15	3- 2	6- 12	-do-
10th. ,, ...	8-2	7- 4	8- 5	-do-
17th. ,, ...	6-6	7- 5	8- 13	-do-
24th. ,, ...	3-1	3- 13	3- 5	-do-
TOTAL ...	151-7	102-5	96 - 8	nil

It will be observed that the gain in crop from plucking with breaking back compared to skiffing, was insignificant, while the labour wasted was very considerable.

In 1932, yields from I, II and III have been practically the same to the end of July; but treatment IV has given 33 lbs. or about 40 per cent. more leaf than any of the others. The tea of treatment I, II and III was pruned in December, and the gain in 1932, from treatment IV undoubtedly comes largely from the earlier pruning: but the bushes look also as if they have been more or less permanently improved in size and vigour by the extra growth left in 1931.

The gain from early pruning is not likely to make up, during 1932, for the leaf lost from failure to pluck in 1931, and we must wait a long time before it can be seen whether simply leaving unplucked and pruning early, will pay as well as skiffing in time to take leaf over any considerable portion of the latter end of a season.

Summary of results of Skiffing Experiments.

Skiffing is followed by loss of crop for the following four weeks. When the interval between skiffing and previous plucking exceeds 3 weeks, practically no crop is taken during the four weeks following skiffing.

Whatever the interval between skiffing and previous plucking, very big crops are to be expected in the fifth and sixth weeks after skiffing, followed by three weeks of small crop, and arrangements should be made accordingly. Skiffing in early October; for example, would be expected to yield crop for only 2 weeks in November, and the tea would be expected to close up quicker than tea regularly plucked. Skiffing therefore must be early to be of any real value. Labour supply should be anticipated and skiffing performed four weeks before a full supply is expected, if tea has been out of plucking for any period exceeding 3 weeks. If labour shortage is to be expected only for a short time, it is best to skiff after 14 days unplucked, and if labour is still short, to skiff again after a further 14 days.

Since a reduced crop is taken from skiffed areas and less plant-food taken off the land, such areas may be expected to show

a relative improvement compared to regularly plucked areas; but experiment at Borbhetta has shown no such improvement in the year immediately following that of the skiffing.

Effect of Variation in Time of Pruning.

Another method of reducing the plucking area in the rains which has been used in practice is to prune tea in the ordinary way just before the rush season is expected.

In order to make the evidence as complete as possible, this subject was investigated by pruning at intervals of 40 days from December 1st. to September 9th., and recording the crops obtained over two seasons. Results in the third season, to-date, are also quoted where of interest.

The tea used was 3 acres of Tingamira tea planted in 1921, and collar-pruned after 2 years in the soil. It was divided into seven blocks of ten plots; and among the 70 plots, 10 sets of 7 plots were selected, so that each set of seven plots had given about same total crop in 1928, and so that one plot of each set fell into each block. (For plan see Quarterly Journal, 1930, part II. page 137.)

The full results to end of 1931, are tabulated below.

Treatment No.	1929		1930				1931		Total crop 1930 and 1931.
	Date of pruning.	crop	Date of pruning.	before pruning.	after pruning.	Total.	Date of pruning.	crop.	
1.	Dec. 20th	8·79	Dec. 2nd	*nil*	10·19	10·19	Dec. 1st	13·29	23·48
2.	,, ,,	8·55	Jan. 11th	,,	8·87	8·87	Jan. 12th	12·10	20·97
3	Feb 20th	7·41	Feb. 20th	,,	7·62	7·62	Feb. 20th	9·62	17·24
4.	Mar. 20th	6·26	Apr. 1st	0·93	5·19	6·02	Unpruned	11·92	17·98
7.	Dec. 20th	8·74	May 11th	1·90	3·44	5·34	,,	11·76	17·10
8.	,, ,,	8·38	Jun. 21st	2·97	1·79	4·76	,,	11·42	16·18
9.	,, ,,	8·61	July 31st	4·07	0·52	4·59	,,	11·92	16·51
10.	,, ,,	8·81	Sept. 9th	6·36	0·05	6·41	,,	13·26	19·67
			Standard error			0·41		0·56	

Crops are given in mds. tea per acre assuming that 100 lbs. leaf give 22½ lbs. tea, which is more nearly what is obtained in practice than 25%.

Results for 1929, were discussed in Quarterly Journal, 1930, page 133, but are included here for completeness. In 1929, treatments 1 and 2 were identical; and 7, 8, 9 and 10 also were identical with 1 and 2 except that these were treated with spray fluids which had no effect.

It will be observed that in 1929, the tea used for experiment 8 gave distinctly less crop than that used for experiments, 1, 2, 7, 9 and 10 although all were under the same treatment. This small inferiority has persisted in 1930 and 1931 : otherwise it may be assumed that all sets of plots would have given practically the same crop if they had been under the same treatment, in 1930 and following years.

In 1930, the intervals between successive prunings are 40 days. The crops taken after pruning naturally decrease as the season is shortened, but the decreases per 40 days difference in pruning time are not regular. The following are the losses, after pruning, compared to crops from pruning 40 days previous to the date mentioned.

	Total.
January 11th.	... 1.32 mds.
February 20th.	... 1.15 ,,
April 1st.	... 2.47 ,,
May 11th.	... 1.75 ,,
June 21st.	... 1.65 ,,
July 31st.	... 1.27 ,,
September 9th.	... 0.47 ,,

The loss from pruning just at the time of the active spring growth of the first flush (April 1st.) stands out as very significantly great. A similar effect was seen in 1929.

In 1929 pruning on February 20th., compared to pruning on December 20th. or 62 days earlier, loses 1.38 mds. tea : a further delay of 28 days only (March 20th. compared to February 20th.) loses a further 1.44 mds. of tea per acre. The loss in 1929, from this pruning at the time of active spring growth is about .05 mds. tea, or about ½% of the full crop from December pruning, for

each day the pruning is delayed, as against .02 mds. tea or 0.2% for each day's delay in pruning during the resting period. In 1929 the tea pruned on March 20th. was not plucked before pruning, but bushes were depleted of reserves by the beginning of the growth of the first flush which was removed by pruning, and the bushes were at the same time depleted of leaves so that the raw food material from the soil could not be manufactured into plant food. A further experiment (No. 6) illustrates the immediate advantage of leaving leaves on the bush when pruning during the growing season.

	1928	1929	1930	
			crop before pruning on April 1st.	crop after pruning up to August 2nd.
	mds.	mds.	mds.	mds.
No. 4	6·25	6·26	0·93	0·37
No. 6	6·20	6·07	0·86	0·65

No. 4 was cleaned out while No. 6 was merely cut across leaving a lot of leaf. By the end of the season, No. 4 had made up the deficit; but the effect of leaving leaf was marked on the early growth. No. 6 for example, was tipped three weeks before No. 4 had any shoots up to the 8″ measure.

As one gets away from the period of active spring growth the loss per 40 days delay in pruning becomes less, till the difference between pruning on July 31st. or September 9th. becomes very small.

The curves facing page 132 show the weekly pluckings from the extremes (December 1st. and September 9th.) and a middle date (April 1st.). Similar crop curves for all the other dates cannot be included as they make the diagram too complicated. For all experiments the 1930, curves up to the date of pruning are, of course, practically identical. The crop curves after pruning on intermediate dates are intermediate between those shown. The

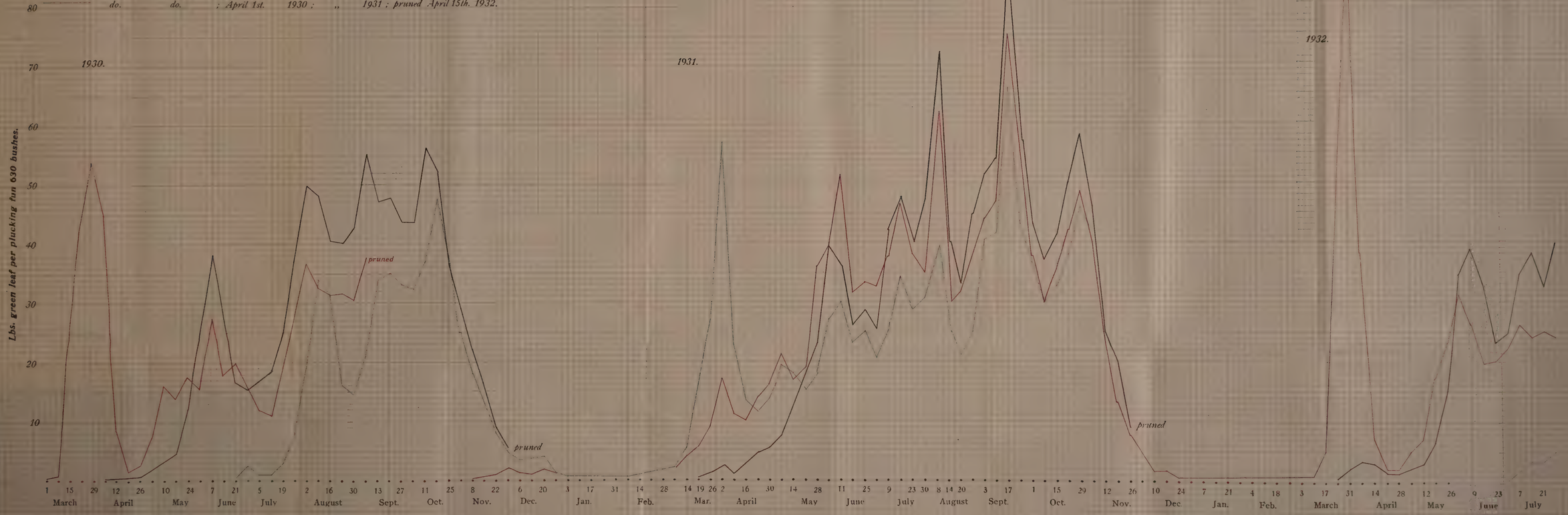
INFLUENCE OF TIME OF PRUNING ON CROPS.

BORBHETTA TINGAMIRA 3-ACRE BLOCK

Pruned annually. December 1st.

Pruned December 1st. 1929 ; September 9th. 1930 ; unpruned 1931 ; to be pruned Sept. 1932.

do. do. ; April 1st. 1930 ; „ 1931 ; pruned April 15th. 1932.


Lbs. green leaf per plucking fun 630 bushes.
80
70
60
50
40
30
20
10
1930.
1931.
1932.
pruned
pruned
pruned
1 15 29 12 26 10 24 7 21 5 19 2 16 30 13 27 11 25 8 22 6 20 3 17 31 14 28 14 19 26 2 16 30 14 28 11 25 9 23 30 8 14 20 3 17 1 15 29 12 26 10 24 7 21 4 18 3 17 31 14 28 12 26 9 23 7 21
March April May June July August Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May June July August Sept. Oct. Nov. Dec Jan. Feb. March April May June July

continuation of the curves during 1931 and part of 1932 shows the effect in after years.

The following figures show interesting parts of the curves.

Cold-Weather Crop.

During the cold weathers both of 1930-31 and 1931-32 plucking was continued weekly. The results are seen in the curves facing page 132.

Crops were negligible in quantity and consisted only of hard banjhi leaf, whatever the interval since last pruning. Such as they were, crops were rather the greater, the *longer* the interval since last pruning.

Late pruning therefore is of no assistance in producing cold weather crop.

Previously (Trial of Time of Manuring, Quarterly Journal, 1930, part II, page 55), it has been shown that late manuring is of little or no assistance in producing cold weather crop. No other method than pruning or manuring can be thought of as likely to influence cold weather crop. We must therefore regard the production of crop in January, February and early March as impossible in the climates of the greater part of North East India. Fair crops may be obtained in November and even December in favourable years, particularly in the Surma Valley : but late pruning will not increase November-December crop, while any gain in December crop from delaying pruning in order to take it, will result in greater loss during the following season. It is recommended therefore that December crop should be taken only from tea which is to be left unpruned.

Since it has been shown that skiffed tea yields its maximum four weeks after skiffing, any tea which got away from want of pluckers and is desired to be used as unpruned tea in the following season, might be skiffed in very early October in order to yield in November, leaving a little growth in the following spring, if thought necessary.

The First Flush.

1930 season.

Tippings from tea pruned in the previous cold weather were negligible at the time of the first flush. The five sets of plots still unpruned at this time gave practically the same crops. Results from the tea afterwards pruned in September are given since these results are plotted facing page .

lbs. leaf per 630 bushes.

Expt.	March		April				Total for season to date.
	22nd	29th	5th	12th	19th	26th	
10	42	55	44	9	1	2	156

The peak of the first flush is on March 29th. A good crop is again plucked a week later, after which the tea shut up until the second flush began to come through in May.

The 1930 season was one of good early rain, favourable for unpruned tea.

1931 season.

All the tea pruned in the previous growing season was left unpruned in 1931. The influence of date of previous pruning on the first flush crop is striking.

lbs. tea per 630 bushes.

Expt.	Date of last pruning.		March				April			Total.	Time since last pruning up to April 2nd.
			7	12	19	26	2	9	16		
4	April 1st.	1930	2	6	14	27	57	23	15	144	12 months
7	May 10th.	,,	2	5	11	22	52	27	19	138	10¾ ,,
8	June 21st.	,,	2	4	9	15	38	19	15	102	9¼ ,,
9	July 31st.	,,	2	5	8	14	28	14	12	83	8 ,,
10	September 9th.	,,	3	6	5	9	17	11	10	61	6¾ ,,
1	December 1st.	,,	...	...	¼	1½	2	1	3	8	4 ,,
2	January 12th.	1931	...	...	...	...	...	1½	1½	3	2¾ ,,
3	February 20th.	,,	...	...	...	...	...	...	1	1	1¾ ,,

In 1931, whatever the date of last pruning, the peak of the 1st. flush is on April 2nd., against March 29th., in the previous

year; but although the date is practically the same, the amount of the first flush is relatively much less in the dry spring of 1931, than with the early rain of 1930. As the tea was maturing, first flush crop in 1931 would have exceeded that of 1930 had seasons been equally favourable.

It will be observed that the date of pruning is still influencing the amount of the flush, crop being greater, according as the interval since last pruning is *greater*.

The first flush of 1931, is little different where the interval since last pruning is 10⅔ or 12 months, but the first flush in 1931, would probably have been rather less from tea pruned in December, 1929, than from tea pruned in April 1930, judging from experiments at Tulsipara.

The tea of Expts. 4, 8 and 10 was again unpruned at the time of the first flush in 1932, and the following results were obtained.

The first flush in 1932.

Expt.	Date of pruning.	March			April			Interval since last pruning up to March 31st. 1932
		17	24	31	7	14	21	
4	April 1st. 1930	5	28	105	39		pruned	24 months
8	June 21st. 1930	4	24	97	33	7	2	21⅓ ,,
10	September 9th. 1930	5	27	101	39	7	2	18⅔ ,,

The peak of the first flush is March 31st., about the same date as in the previous two years.

There is no significant difference between these results. The set of plots devoted to Expt. 8, has always been rather poorer than average. A difference of 5⅓ months in the interval since pruning makes no difference when the interval is long.

The suddenness of the appearance, and the equally sudden close, of the first flush are to be noted. In all the three years it occurs at just about the same time of year and lasts for just 3 weeks : and in practice, on gardens, these points are often missed.

In 1932, for example, on March 17th., there is practically nothing to pluck; on March 24th., very little; but on March 31st., there was an enormous flush. If it were not taken, or if the small flush of March 24th., were not taken, there would remain very largely, only banjhi leaf to take, and future crop also would be affected adversely. Plucking of unpruned tea must be close and at frequent intervals from about the middle of March till the end of the first flush.

The magnitude of the first flush in 1932, does not indicate a season favourable for unpruned tea : it is quite the reverse. The flush is greater than in previous years only because the tea is young, is being regularly manured, and is coming on better and better every year.

Between 1st. and 2nd. Flush.

The period between the two flushes lasting roughly from mid-April to mid-May is always a dull time, whenever the tea be pruned. When, on account of early drought, the normal first flush has practically been lost altogether, this period is not quite so dull for unpruned tea, and unpruned tea always fills this gap better than pruned tea. Still a period of depression may always be looked for, and nothing can be recommended for improving crops at this time of year. In 1931 the tea pruned on the 10th. May, 1929, gave the best crops during this lull, but just before the second flush is not a time which can be recommended for pruning any large area.

Skiffing about the middle of March, with consequent loss of the first flush soon to be expected, might prove useful in getting more crop in the dull period, in rare cases where the first flush is likely to be greater than can be managed by the plucking force available. Such skiffing about mid-March or a little earlier might also prove preferable to leaving tea unpruned in years where the first flush is certain to be little on account of early drought, and tea so treated should leave bushes giving larger, more easily plucked, shoots during the remainder of the season than tea left unpruned : but no experiments on this point are recorded.

The second Flush.

1930 results.

lbs. leaf per 630 bushes.

Expt.	Date of pruning.	May 17	May 24	May 31	June 7	June 14	June 21	June 28	Total.	
1.	December 2nd. 1929	5	11	25	38	27	16	15	147	
2.	January 11th. 1930	2	7	15	36	30	16	10	116	
3.	February 20th. ,,	½	2	4	16	20	22	11	76	
4.	April 1st. ,,	...	...	...	...	...	...	½	nil.	
7.	May 10th. ,,	...	...	...	...	...	...	...	nil.	
8.	June 21st. ,,	12	17	16	27	19	pruned		...	
9.	July 31st. ,,	13	19	16	26	16	16	12	118	123 mean.
10.	September 9th. ,,	14	18	15	27	18	20	16	128	123 mean.

The tea of experiments 8, 9 and 10 was still unpruned at the time of the second flush. It will be observed that unpruned tea gave a smaller second flush than tea pruned in December, about the same as tea pruned in January, and much more than tea pruned in February.

The peak of the second flush is in all cases June 7th., except in the case of the tea pruned on February 20th., in which case a delay of 80 days in pruning makes the second flush about a week later.

Experiments 1, 2 and 3 show the effect on the second flush of delay in annual pruning.

In 1931, all the tea pruned in the growing season of 1930 was left unpruned.

The Second Flush in 1931.

lbs. leaf per 630 bushes.

Expt.	Date of last pruning.	May 21	May 28	June 4	June 11	June 18	June 25	July 2	Total	Interval between last pruning and June 11th.
4.	April 1st. 1930 ...	15	18	27	29	23	25	20	115	14½ months.
7.	May 10th. ,, ...	24	25	29	32	24	31	26	188	13 ,,
8.	June 21st ,, ...	18	27	36	31	30	29	25	197	11⅔ ,,
9.	July 31st. ,, ...	21	30	37	39	32	30	29	218	10⅓ ,,
10.	September 9th. ,, ...	19	36	39	52	31	34	33	244	9 ,,
1.	December 1st. ,, ...	19	23	39	36	29	34	30	210	6½ ,,
2.	January 12th. 1931 ...	11	16	30	42	25	21	20	165	5 ,,
3.	February 20th. ,, ...	3	6	12	25	22	27	15	110	3⅔ ,,

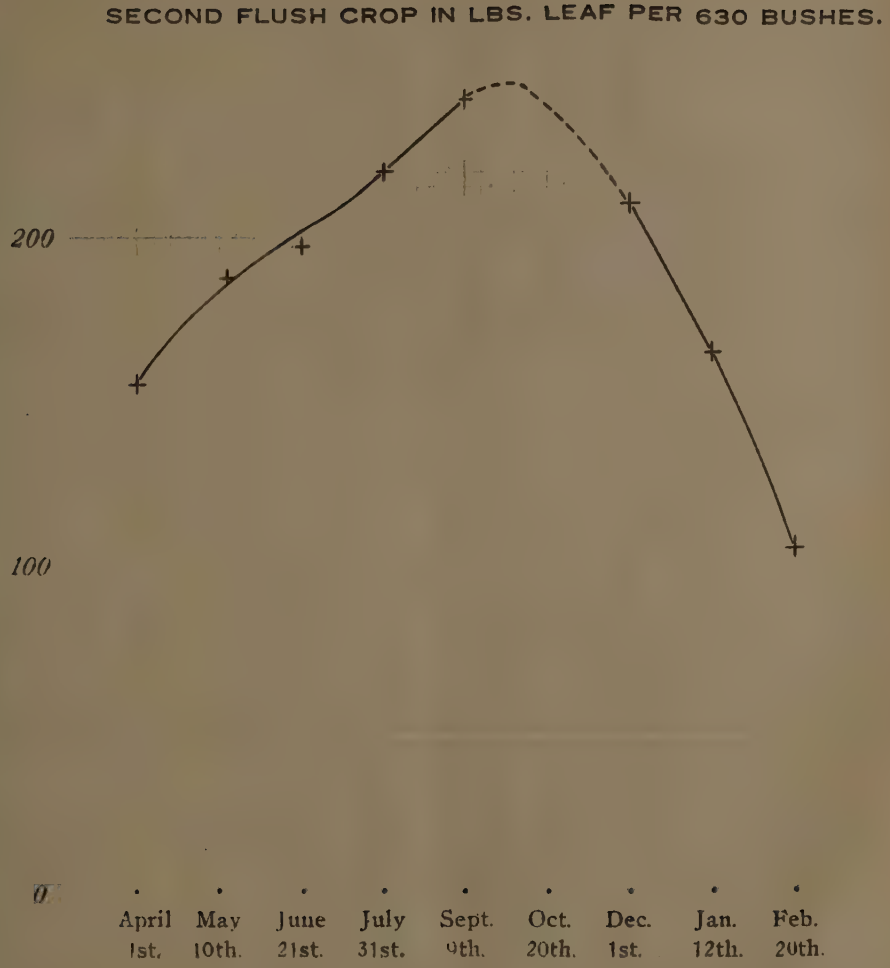
The second flush in 1931, does not appear so suddenly in 1931, as in 1930, but the peak pluckings are in every case the 4th. and 11th. of June, except in the case of the last pruned tea (February 20th.), which is again about a week later.

The long gap (produced by the drought of that time) between the 2nd. and 3rd. flush in 1930, is considerably shortened in 1931, but the graphs show the normal lull after the second flush quite distinctly.

With regard to the amount of the second flush it will be seen that the maximum was obtained from the tea pruned on the previous September 9th.

Pruning on July 31st. or 40 days before September 9th. loses 26 lbs. in crop, or 0.65 lbs. leaf per day earlier in pruning. Pruning on December 1st. or 83 days later than September 9th loses 34 lbs. or 0.41 lbs. leaf per day later in pruning. It is unfortunate that we have no date of pruning between September 9th. and December 1st. : but it appears at least very probably that some date of pruning between these two but nearer to September 9th., would have given the biggest second flush. If the results are plotted on a curve, the reason for this guess becomes clearer. The dotted portion of the curve, which represents that part which has to be guessed would indicate pruning at some time in October as that which would have given the biggest second flush.

Referring back to the crop curve of 1930, it will be seen that crops in that year fell off very rapidly after October 18th., and it is probably that pruning soon after that date would have given the best reults in second flush crop in 1931. In 1931, the season had a better "back end" and good crops were maintained till about November 5th : the best date for pruning to get maximum second flush crop in 1932, without undue loss of 1931, crop probably would have been about November 12th. Where tea has been left unplucked for want of labour for plucking, there is no need to delay pruning. Second flush crop may not always be increased by pruning in October, as soon as labour can be spared rather than in November, but second flush crop will not be decreased by the


SECOND FLUSH CROP IN LBS. LEAF PER 630 BUSHES.
200
100
0
April 1st.
May 10th.
June 21st.
July 31st.
Sept. 9th.
Oct. 20th.
Dec. 1st.
Jan. 12th.
Feb. 20th.
Date of Pruning.

earlier pruning, while first flush crop and total crop for the following season, certainly will be increased.

First Second Flush Crops in the Dooars.

The results from experimental plots in the Dooars provide interesting comparisons with those from Borbhetta. In 1930, none of the tea on the Tulsipara plots was unpruned; but some experimental plots at Kumargram show, in that year of favourable spring rain, results very similar to those at Borbhetta. Unpruned tea gave over one-sixth of its total crop for the season in the total of the last plucking of March and the first plucking of April, just about the same time as tea at Borbhetta gave the same fraction of its crop.

In 1931 and 1932, the experiments at Tulsipara included trials of unpruned tea, both seasons being characterised by serious spring drought.

At Tulsipara in 1931, the pruned tea increased in weekly yield from the beginning of the season, giving the peak of its second flush on May 26th. and June 2nd., after which crops decreased just as they did in Assam, till the third flush came through.

In 1932, the crop curve has been similar. Because of the much worse drought, crops remained very small till mid-May, after which the rate of weekly increase was very great, the peak of the second flush being on May 31st.

The pruned tea, then, behaved just as it does in Assam.

Unpruned tea in 1932, also behaved at Tulsipara much as unpruned tea did at Borbhetta, giving a distinct first flush with its peak on March 31st., and a distinct second flush with its peak on May 31st., although by reason of more serious drought, crops were relatively small at Tulsipara.

In 1931, however, the unpruned tea behaved very differently. The biggest weekly crop was taken on April 21st., and crops remained good for the two succeeding weeks, after which weekly

yields fell away rapidly till June 9th., after which the tea was pruned.

In 1931, then, the crop curve from unpruned tea was abnormal. There were no indications of "peaks" at the normal times of either the first or the second flush; but, instead, a peak about half way between the two. Several factors contributed to this effect. First, the tea had been pruned late in the previous year, near the normal time of the first flush, and, at Borbhetta, pruning at this time does increase the April crop of the following year. Secondly the normal first flush failed on account of drought so that the unused stored food supply was available for a later flush. Thirdly, both mosquito blight and red spider were very active agents in reducing crop when the second flush should have been showing up.

The loss of second flush tea (pruned in this case) which may occur from red spider is well illustrated by results of spraying experiments at Tulsipara in 1932.

Nine plots of 200 bushes each were sprayed with lime sulphur on April 25th. just when red spider began to show generally. Nine adoining plots were left unsprayed.

The following crops were recorded.

	Total to April 23rd. 8 pluckings.	April 30th, to May 21st. 4 pluckings.	May 28th. to June 18th. 4 pluckings (second flush)
Sprayed ...	58 lbs. 7 ozs.	62 lbs. 7 ozs.	358 lbs. 3 ozs.
Unsprayed ...	58 „ 10 „	83 „ 11 „	238 „ 11 „

For four weeks after the spraying, crop was slightly reduced; but in the next four weeks of second flush crop, the sprayed plots remained free from red spider while the unsprayed were badly attacked. The result was that the spraying gave an increase in second flush crop of 50% equivalent to about ½ md. tea per acre.

An effect like this in 1931, when red spider was quite as bad, would be a big factor in preventing the normal second flush peak from showing up.

Comparison of pruned with unpruned tea in different districts.

In Assam unpruned tea is generally unpopular. Quality is considered to suffer, in comparison with pruned tea, even in the second flush teas, although, of course, quality from first flush unpruned is very greatly preferable to the tippings from pruned tea. After the second flush there can be no doubt that the small hard shoots from unpruned tea, with a large percentage of "banjhi", give much poorer quality than from pruned tea, besides using more labour per lb. of tea.

It is very generally considered, also, that unpruned tea does not pay in crop; and long continued experiment at Tocklai shows no gain in crop from the use of unpruned tea. In the Dooars and the Surma Valley, however, unpruned tea is considered to yield better than pruned tea.

Comparsion of results from Borbhetta and Tulsipara show that unpruned tea continues to yield better than pruned tea for a much longer time in the Dooars than in Assam.

On the experimental area at Tulsipara, plucking is as fine and as close as at Borbhetta, or as nearly so as the labour can be induced to do it.

As the areas concerned are different; for comparison, crops are expressed in lbs. green leaf per acre.

lbs. green leaf per acre 1932.

	To end April.	May	June	July	Total to end July
Tulsipara					
(1) Unpruned tea ...	308	386	269	359	1322
(2) Tea pruned in December ...	67	333	225	299	924
ratio (1) to (2)	4·6	1·2	1·2	1·2	1·44
Borbhetta					
(1) Unpruned tea ...	727	204	468	386	1785
(2) Tea pruned in December ...	45	106	601	568	1320
ratio (1) to (2)	16·5	1·9	0·8	0·6	1·35

This season, crops at Tulsipara have been unaffected by mosquito blight to-date, but red spider has been bad, and weather unfavourable. The same is true of Borbhetta. At both gardens the lull following the second flush was abnormally severe and prolonged, though good crops were taken in the last week of May and first fortnight of June, and a good third flush appears to be starting near the end of July.

The small crops for May at Borbhetta are due to severe "green-fly stunt", with some rim-blight. The small crops for June at Tulsipara may be ascribed to red spider and excessive rain.

The Third Flush and Rains Flushes.

The second flush is always followed by a period of depressed crop which may last only for two weeks, as in 1931, or for longer if weather has been unfavourable, as it was in 1930.

In normal years, weekly crop is fairly regular from about the 2nd. week in July till about the end of October. Crests and troughs appear in the crop curve but not at any predictable dates : their occurrence appears to depend entirely on weather factors varying from season to season.

A curve like that of 1931, showing strongly marked rushes and lulls in growth, makes good plucking more difficult then in a year of more even rains growth as shown in the 1930 curve. Other things being equal the more even growth of 1930 would be expected to produce the better average quality.

It will be observed that during the rains both in 1930 and 1931, the peak crops, and intermediate periods of depressed growth, appear on the same dates, the shape of the curve not being affected by the date of pruning.

Crops of the third flush and the rains crops generally are greatest for the pruning of December 1st., among the pruning dates tried. It is probable that still earlier pruning would have done better, probably some date in October best of all, but no direct experiment on that point has been made.

The Last Flush.

The last flush is of special interest, both because it is taken at a time when labour again becomes available for complete plucking, and because it may show autumnal flavour, while even without definite flavour leaf grown in this cooler part of the season generally produces tea of more desirable character than that grown in the rains.

The influence of date of pruning on the last flush is illustrated in the following tables.

The last flush 1930.

Expt.	Date of pruning.		lbs. leaf per 630 bushes.									Total.
			October				November					
			4	11	18	25	1	8	15	22	29	
1.	Dec. 2nd.	1929	43	56	52	37	28	21	15	9	6	267
2.	Jan. 11th.	1930	41	50	47	38	26	20	14	8	6	249
3.	Feb. 20th.	1930	38	51	48	31	25	20	13	8	5	244
4.	April 1st.	1930	32	37	47	36	24	17	13	7	5	221
7.	May 11th.	1930	32	28	32	27	24	16	11	7	5	182
8.	June 21st.	1930	14	25	27	23	15	10	7	5	3	129
9.	July 31st.	1930	2	5	12	16	4	3	5	5	3	55
10.	Sept. 9th.	1930	...	...	...	...	...	½	1	2	1	4½

It will be observed that the later the pruning the smaller is the total of the last flush. There is no gain in end-of-season crop from late pruning but the reverse.

Crops from ordinary cold-weather pruning (December 2nd. to Jaunary 20th.) may be considered to have become practically equal in the last flush; but from later prunings the late-season crop becomes progressively smaller as pruning is more delayed.

The Last Flush in 1931.

Tea pruned in the cold weather 1929-30, was pruned again twelve months later in 1930-31. The tea pruned in the growing season 1930, simply lost about eight weeks of the season. To

prune it similarly in the following season must have entailed similar, though possibly smaller, losses. All the tea pruned in the growing season of 1930 was therefore left unpruned for season 1931. The following were the crops obtained in the last flush in 1931.

Expt.	Date of last pruning.		October 8	15	22	29	November 5	12	19	26	Total.
4.	April 1st.	1930	28	32	38	46	42	23	11	7	227
7.	May 11th.	1930	23	28	35	43	39	18	11	5	202
8.	June 21st.	1930	24	28	34	40	36	18	9	5	194
9.	July 31st.	1930	24	30	36	44	38	19	10	5	206
10.	Sept. 9th.	1930	29	35	42	48	39	25	13	8	239
1.	Dec. 1st.	1930	38	42	51	58	45	25	17	9	285
2.	Jan. 11th.	1931	35	40	51	57	45	30	12	10	280
3.	Feb. 20th.	1931	35	39	46	56	45	25	19	12	277

The last three experiments (numbered 1, 2 and 3) again show that crops from pruning on different dates in the previous cold weather are practically equal in the last flush. There is no gain in late season's tea from late pruning. Unpruned tea whatever the interval from last pruning gives a smaller last flush than pruned tea.

The last flush of 1931, with a peak on October 29th., was an abnormally late one. Normally the peak is about mid-October, after which crop falls away. This rush of autumnal growth in 1931, which was general, and due to weather conditions, ruined autumnal flavour.

Summary of Conclusions for Results of Experiments on Different Times of Pruning.

(1) *Unpruned Tea.*

These trials show no gain in crop from the use of unpruned tea. Previous trials at Tocklai also showed equal crops over 12 years whether the tea was pruned annually, or every other year. No gain is to be expected in any long run, since the crop must be limited by the food supply. Bad pruning may reduce the efficiency of a bush so that it yields less than it should, for the food

it receives; and in this respect alternate year pruning, by leaving large snags and diseased wood on a bush for two years, instead of small snags for one year, would be expected to be less efficient than annual pruning. Worse effects from drought, also, would be expected from a system which leaves masses of leaves to transpire water, and dry out the frames, when soil and atmosphere are very dry.

It seems generally agreed that except for the first flush, quality is worse from unpruned than from pruned tea, at any rate in the plains.

The only point in favour of unpruned tea (apart from some saving in cost of pruning) is that it yields more crop early in the season, and less in the rains, than pruned tea does. This offers no advantage during the rains, since the smaller crop is generally found to require more labour per acre for plucking, on account of the very small size of the shoots. We cannot, therefore, find anything in favour of unpruned tea for use throughout a full season, if there is labour sufficient for complete plucking of pruned tea.

Where, however, it is known that a certain proportion of the garden cannot be fully plucked throughout the season, it would seem sound to leave that area unpruned. To the end of July, the smallest advantage of which we have record from unpruned tea against tea pruned in December, is an increase of 35%, and generally it is nearer 50%. When labour becomes insufficient for the plucking of the whole garden, these unpruned areas can be left unplucked. They can then be skiffed if labour is expected to become available later, or simply left to be pruned early (October) to yield a good early crop in the following season.

(2) *Pruning in the Rains.*

The experiments quoted show this to be a complete failure, if repeated annually. It means, simply, that about eight weeks of the heavy-flushing season is lost, and there is no gain in the succeeding season.

At Tulsipara, pruning in June, when mosquito blight was active, was followed by such virulent attack that practically no crop was taken for the remainder of the season. Neither have these plots done very well to-date in the following season. Rains pruning was an experiment well worth trying, but so far results have been disappointing. If pruning is in alternate years rains pruning may do well, but we have not yet results to record.

(3) *Time of Pruning in the Resting-Season.*

The time of pruning in the cold-weather has been shown to be of great importance. The earlier the tea is pruned, the earlier does it yield, without losing anything at the end of the season. It is shown that whenever the tea is pruned it yields its second flush crop at practically the same date; but the amount of this valuable tea is greater as pruning is earlier. Some time in October appears to be the time of pruning to secure maximum second-flush crop in the following season. This is too early a date for tea in full plucking since it would lose good end-of-season teas with their chance of autumnal flavour : but any tea not being plucked is recommended for pruning in October.

For tea in full plucking, pruning should be started as soon as the crop reaches small proportions. About the 3rd. or 4th. week in November would suit most Assam gardens, which get no marked autumnal flavour, but do get good prices for their second flush teas. In the Dooars where autumnal flavour is more common, or in the Surma Valley, where a longer season is common, a somewhat later date, to be determined by local experience, should be adopted.

Very late pruning, February or March, as is popular in parts of the Dooars is probably quite good for tea which will not be pruned again for two years : but experiments at Tulsipara provide no support for late pruning of tea to be pruned annually. If drought is serious there will be less gain from the early pruning, but there is still a gain. The late pruned tea escapes red-spider better, and is later attacked by mosquito blight, but crop still shows a loss compared to early pruned tea.

In the experiments quoted, all the tea compared was pruned and cleaned out at the same time. It would be expected, however, that the time of pruning (cutting across) would be a bigger factor in producing early crop, than the time of cleaning out.

Experiments on cleaning-out will be reported in full in the next issue of the Journal. Here it may be stated :—

(1) tea not cleaned out shows as big a gain from early pruning as does cleaned-out tea.

(2) tea cut-across in December, and cleaned-out soon afterwards has given to the end of July practically the same crop as tea cut-across in December and cleaned out at the end of February, although the latter had growing *banjhis* removed from it, and has always looked more empty, though there is little difference in that respect at the end of July.

In order, therefore, to get pruning time really early enough to make a considerable difference to crop, it is suggested that the garden should first be pruned by cutting across without cleaning out; cleaning out to follow later.

Two objections to this procedure have been raised.

First, that the concentration of almost all the labour on pruning interferes seriously with the early cold-weather deep cultivation, particularly as cutting across is often found possible at a cheap rate only by men. All one can say in reply to this objection is that of the two, early pruning is considered of more importance than early deep hoeing. In fact, at Borbhetta, a deep hoe once in five years is found amply sufficient, though this may not be true of stiffer soils. The garden should, of course, be clean, but it is generally possible to get rid of the jungle accumulated by enforced neglect in August and September, by light hoeing in October and November. Any deep hoeing to be done, can then wait till January or February, when it serves the purpose of burying the prunings of the first cut-across.

The second objection is that pruning in two operations is more costly than pruning in one operation. Some gardens do not find it so, but generally pruning in two operations has been more expensive.

At Borbhetta last cold-weather on moderately good tea giving about 10 mds. per acre, pruning and cleaning out in one operation cost about Rs. 16/- per acre.

Cutting across cost about	...	Rs. 8/-
Cleaning-out afterward costs about	...	,, 13/-
	Total	,, 21/-

These costs are all high, for good work, but probably the increase in cost for two-shot as against one-shot pruning of about 30% may be taken as indicative of the relative increase in cost on most gardens where this kind of work is tried for the first time.

The cost of cutting across is very high compared to most gardens. At Borbhetta any attempt to reduce it led to such awful cuts that their repair at the second pruning put up the cost of cleaning out to the same as was paid for bushes not cleaned out; so that the total cost of pruning was not decreased. Still on many gardens good work has been seen much more cheaply performed. It is considered essential, from all points of view that the first cut-across is such that no repair work is necessary on the cuts left, attention during cleaning out being confined to removal of *banjhi* and weak shoots, snags and diseased wood, except for a few shoots which are running across the bush. If the first cut is really good, the cost of the second operation of cleaning out should be reduced as coolies become accustomed to the work. It has been shown also that cleaning out every year is not necessary. If only two-thirds of the garden is cleaned out, early pruning can be obtained at about the same cost as pruning and cleaning out the whole garden in one operation and finishing late. At Borbhetta we do not mind the additional time spent on pruning, because if they were not pruning it would be even more difficult than it now is to find remunerative work for the labour during the cold-weather : a

large number of gardens are in the same position. At Borbhetta last cold-weather the additional cost of pruning did not raise the wages paid.

Pruning per acre used	...	48 haziras.
Deep hoeing per acre used	...	20 ,,
		68 ,,

With 26 working days per month, if only one cooly per acre were used, both pruning and deep hoeing would be finished soon after the middle of February if they started on December 1st. : and we still have slack times in March, April, and early May for odd jobs, like roads, drains, house repairs etc.

A third objection may be urged from a theoretical standpoint. Assuming, as probably we may, that crop is limited by the available food supply; then, if the food supply remains constant we cannot expect always to maintain bigger crops by allowing crop to be grown over a longer period of the year (which is what early pruning amounts to). Still a bigger proportion of the crop will continue to be grown early, which is a great advantage; and, if it is found, after a few years, that increased manuring is necessary to maintain the late crop, this extra expenditure will be found to pay.

Assuming that a month earlier in pruning gives 10% more crop, then on 10-md. tea, an extra maund of tea is maintainable for about Rs. 3/8/- (inclusive) for manuring. On probably the majority of gardens, however, tea does not yield up to its full capacity for the manure it receives. This is generally because all the tea grown cannot be plucked, though inefficiency of pruning or cultivation, or the presence of disease, may be acting in reduction of crop. Very often therefore early pruning may have the effect of allowing bushes to use more completely the food available, and increased manuring need not be considered till a tendency to falling crop or the appearance of the bushes, indicate the need.

THE STRUCTURE AND GROWTH OF THE TEA BUSH

1. The Plant Cell

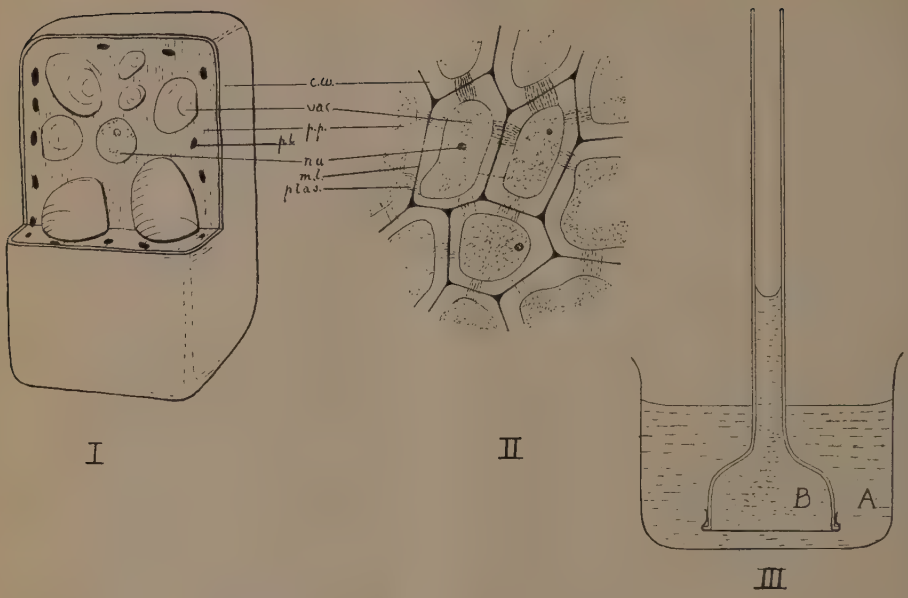
BY

W. Wight

In this and subsequent articles an attempt will be made to describe the structure and functions of the tea plant. The first articles of the series will make no pretensions to having any immediate practical applications. The principles involved, however, are necessarily fundamental to practice, so long as the tea industry depends on the tea bush. The structures and principles to be described are of importance in so far as they are altered and modified by cultural operations and manufacture. These articles will make it possible, when the Botanical investigations at Tocklai are sufficiently advanced for publication, to avoid constant explanatory digressions. Unless specifically mentioned as applying to tea, the following account refers to plant cells in general.

The Plant Cell

All living things consist either of one cell or of an aggregate of cells. A single cell, with very few exceptions, is quite microscopic in size, and may be almost any shape. In the case of the tea bush we are dealing with a complex mass of cells which number billions. A cell, either plant or animal, is defined as a nucleated mass of protoplasm. Plant cells have a cell wall—animal cells have no cell wall. The wall is not an essential part of the cell, and protoplasm and nucleus can live without a wall. The terms protoplasm and nucleus need some explanation. The essential cell substance consists of a watery jelly (colloidal proteins) which is usually referred to as the protoplasm. Inside this mass is a much smaller body, really a specialised part of the protoplasm, which is called the nucleus. The nucleus is an energy centre, and is, moreover, necessary for the formation of further cells. New cells, on the for-



I II III

I. *Plant cell partly cut open: diagram showing the different parts of the cell.*

c.w.—cell wall.
vac.—vacuole.
pp.—protoplasm (shaded).
pl.—plastid.

II. *Section through cells from the persimmon fruit. Cells with very thick walls penetrated by plasmodesma (protoplasmic connections).*
ml.—middle lamella.
plas.—plasmodesma.
(After Eames and Mac Daniels).

III. *Apparatus to demonstrate osmosis. The outer vessel contains pure water A. The tube contains sugar solution B. A membrane is fastened across the bell mouth of the tube.*

mation of which a large part of the growth of the plant depends, always arise by the division of pre-existing cells. The protoplasm can live in the absence of a nucleus, but without a nucleus cell division cannot take place. Fig. I illustrates a typical plant cell. It will be seen that the protoplasm does not fill the whole of the space enclosed by the cell wall. There are large cavities inside the protoplasm, and various grain like structures (plastids) are embedded in the mass of the protoplasm itself. The cavities are spoken of as vacuoles and are typical of cells which are ceasing or have ceased growth. As the cell increased in size, the protoplasm developed cavities which filled with water and materials in solution. The solution (cell sap) in the vacuoles consists largely of water, in which is dissolved small amounts of various substances. Inorganic salts such as those of sodium and potassium, carbohydrates, such as cane and grape sugars and dextrine, nitrogenous compounds related to the proteins, and alkaloids, are present in the cell sap. Many important substances known as enzymes are found in the cell sap, and, in the tea plant, practically all of the tannins in the leaf are present in the vacuoles. How to efficiently liberate these tannins is one of the problems of manufacture.

The nucleus is a highly specialised, rounded or ellipsoidal portion of the protoplasm, separated from the rest of the protoplasm by a definite membrane. Chemically, the nucleus differs from the protoplasm in containing large quantities of phosphorous. The nucleus plays a prominent part in the very complicated process of cell division. A nucleus is always formed by the division of a pre-existing nucleus.

The plastids are elliptical or circular discs embedded in the protoplasm, and with a structure much the same as that of the protoplasm itself. The plastids are often arranged in a layer towards the outside of the protoplasm. The surface of a plastid is somewhat sponge like, and according to whether the sponge is impregnated with green colouring matter, other colouring matter, or no colouring at all, the plastids are spoken of as chloroplasts, chromoplasts, and leucoplasts. The plastids are concerned with

building up complex food substances from simple inorganic salts. The plastids also serve for storing food; each starch grain inside the plant is built up inside a plastid. It seems fairly certain that plastids always arise by the division of a pre-existing embryonic plastid at the time of cell division. One type of plastid may, under different conditions, change into another type, as may be seen in the greening of a potato tuber, where the colourless leucoplasts, which were originally concerned only with the storage of food, develop (under the influence of light) a green colouring matter, chlorophyll, and then function as food producers. The green colouring matter (chlorophyll) of the tea plant is located in chloroplasts. The rest of the plant is colourless; seen with the naked eye, the whole of the plant looks green, due to the fact that a single cell is far too small to be seen with the naked eye. The animal world obtains its food in a relatively complex form from plants. The plant itself has to build up its complex structure from simple substances such as water, carbon dioxide gas (the gas in soda water), nitrates, and small quantities of sulphur, phosphorus, iron, potassium, etc., which are absorbed by the roots from the soil. Chlorophyll is of the greatest importance, for without chlorophyll the plant cells cannot utilise these simple food substances (light is also necessary). The function of chlorophyll is that of a sensitiser: it collects energy in the form of light and utilises this energy in chemical reactions. The colour of chlorophyll is such that it collects the rays of light from which the greatest amount of energy may be derived: a green substance absorbs red light, and the greatest amount of energy in white sunlight—which is really composed of rays of numerous different colours—is associated with the red rays. Silver salts, from which photographic plates are made, are normally unaffected by the red light of the dark room lamp, but can be sensitised to red light by a solution of chlorophyll. Red rays are, however, quickly absorbed by water, whereas the green rays of sunlight penetrate to a much greater distance. In this respect it is interesting to note that deep sea plants (seaweeds) are very frequently red, red pigments being able to absorb green light. The amount of chlorophyll in a cell exposed to light varies from time to time. The

conditions affecting this variation are complex : with bright light and too low a temperature, chlorophyll is destroyed faster than the living protoplasm replaces it, and the plant becomes paler in colour. The yellow-green colour developed by unshaded tea during the cold-weather is probably due to a similar destruction of chlorophyll.

The whole of the general groundwork of the cell has been referred to above as protoplasm. Actually, the groundwork is more complicated than this designation would imply. In addition to the plastids, various other cell inclusions occur. The mass of the cell (excluding the cell wall) is chemically a jelly like (colloidal) mass of many proteins, some simple and some highly complex. Between many of these there are no physical boundaries, though some of the simple proteins occur in a crystalloid form as definite cell inclusions, and others again occur in the cell sap in the vacuoles. It is fairly certain that certain classes of the more complex proteins are more definitely associated with the properties of life than other proteins. The simple proteins, such as occur as cell inclusions and in solution in the vacuoles and mixed amongst the mass of the protoplasm (to a small extent) may be regarded as reserve food materials, and as such fluctuate considerably in amount. The rest of the proteins are more intimately connected with life, especially these which are almost insoluble in gastric juice (the nucleo-proteins). One sometimes speaks of reserve proteins and protoplasmic proteins, referring, in the latter case, to those proteins most intimately associated with the life of the cell. Whilst physically the protoplasm is a colloidal substance, and chemically it is a mixture of proteins, these definitions are in the terms of a non-living world, and only refer to dead protoplasm. Even supposing that they apply to living substance, the qualification *living* shows that the definitions of chemistry and physics are inadequate. The properties of life, such as irritability and reaction to stimuli, cannot as yet be explained in simpler terms, and we are therefore inevitably bound down to the fact that the cell is the ultimate unit of living structure.

The cell wall, such as is found around all plant cells, is a product of the living protoplasm. In tissues, *i.e.*, aggregates of similar cells, the walls of all the cells are intimately joined together, so that a thin section of the material appears as a *cellular* structure, referring to the very obvious walls. In the early days of Botany, before the nature of the living unit was fully recognised, the name *cell* was used to designate each of the little rooms partitioned off by the walls, only secondary attention being given to the living substance inside the rooms. Even in a very complex tissue, the walls belonging to individual cells can be recognised, due to the fact that the thickness of the walls is built up of laminations. Initially one cell divides: the initial dividing wall remains of a different nature from the subsequent layers deposited on each side of it by the two new cells. By the application of suitable solvents to pieces of plant tissue, it is possible to dissolve the middle layer (middle lamella) alone and separate individual cells, each surrounded by its own cell wall. In the plant body, the living protoplasm of one cell frequently communicates with the protoplasm of adjacent cells. There are small pores in the cell walls, and through these pores the living protoplasm of one cell is continuous with the protoplasm of another cell (Fig. II). In dead cells, such as those of the wood, the positions of the original protoplasmic connections (plasmodesma) may become the sites of definite holes (pits) in the walls. It is important to remember that the cell wall is a relatively stout, non-living structure (composed of cellulose). In young and immature cells the wall often possesses the properties of extensibility and elasticity to a marked extent. Also, in special cases, the nature of the walls may be so modified as to possess, within the limits of its elasticity, a very high tensile strength. These facts, coupled with the exceedingly minute size of the cell (the diameter of the leaf cell averages 1/1,000″) becomes of great importance in any considerations of rolling. On account of the size of the cells alone, the mechanical strains imposed in a normal roll would appear to be unlikely to cause an actual rupture of the walls of the majority of the cells in the leaf. This condition is realised in practice, for a microscopic examination of manufactured tea shows extremely little cell (wall) break-

age. The actual amount and nature of the breakage varies in different types of roll. A more detailed discussion of this subject is reserved for a future article.

Many of the life activities of the cell, such as changes in the nature of food reserves, are carried out with the aid of enzymes. The enzymes are found in solution in the cell sap. Growth, consisting of the formation of new plant material, depends on a number of complex chemical reactions which occur inside the cell. Most of these chemical reactions are carried out with the aid of enzymes. Enzymes are substances produced by the protoplasm, and are very similar to the catalysts of the chemist. A catalyst is a substance, a very small quantity of which can greatly speed up a chemical change (though it does not initiate the change) and itself usually remains the same in nature and amount at the end of the reaction, *e.g.*, a very small amount of finely divided platinum greatly speeds up the decomposition of hydrogen peroxide by alkalies. In the preparation of oxygen gas from potassium chlorate, a substance known as manganese dioxide is used as a catalyst to speed up the reaction. The enzymes of plant cells differ from catalysts only in degree. They are rather more selective in their action and do not always carry the reaction to the same degree of completeness as an inorganic catalyst. Very concentrated extracts of enzymes can be made, but it is doubtful if any have actually been isolated in a pure condition owing to the great difficulties of purification. The presence of enzymes can only be inferred from the properties of plant extracts. Different enzymes are known to be concerned in different processes in the cell, *e.g.*, the enzyme diastase breaks down reserve starch to the sugar maltose. In cases where the starch reserves are replaced by reserves of inulin, an enzyme, inulase, breaks down the reserves, when required, to the sugar levulose. Enzymes are formed by the protoplasm at different times in the life of the plant, and once formed, the enzymes may persist for some time, even after the death of the protoplasm. Different conditions affect the activity of the enzymes, *e.g.*, enzymes can be completely destroyed by heat, and most enzymes can be poisoned by such substances as corrosive sublimate, ether, or formalin. Yet they are not living sub-

stances—the foregoing properties are not necessarily those of life and are also shown by non-living metallic catalysts. Plants may killed in such a way that the enzymes still show all their characteristic properties. It may seem at first sight as though such dead plants would carry out their general life processes as do living ones. The difference, however, lies in this. When plants are killed without the destruction of their enzymes, the physiological system of the cells is completely disarranged, with destruction of the interrelations that obtain between the different constituents of the living cells. In the living organism, the different cells and cell components appear to be bound together and interrelated so as to form a harmonious whole, but the parts of a dead cell appear to be quite unrelated and merely enclosed within a common membrane; the interrelation that make the parts a living unit is absent. In dead cells there is no correlation between the activities of the different enzymes, and the activity of one enzyme is not regulated by that of another, so that a chaotic state of affairs exists instead of orderly and rythmic activity. Moreover, one enzyme may attack another: actually, what happens when the protoplasm is killed, is that the protein destroying enzymes eventually predominate and protein decomposition (hydrolysis) takes place. On the whole, one may regard the cell as a laboratory where complex chemical reactions are being carried out; the workers in the laboratory are the enzymes and these are controlled by the property of life which resides in the protoplasm. As conditions, approaching those which result in death, begin to affect the protoplasm, so are the enzymatic activities of the cell likely to be affected. It is probable that enzyme activity plays a large part in withering as well as in fermentation. Also, the extent of enzyme activity may be materially influenced by the amount of tannin in the leaf, as tannins are known to inhibit the activities of certain enzymes.

Reserve food materials have been mentioned, *i.e.*, starch and inulin. Permanent food reserves are usually present in the cell in an insoluble or relatively inactive form. It will be seen later that the presence of large quantities of materials in solution would materially interfere with the normal activities of the cell.

Mention has been made of the fact that the protoplasm and proteins of the cell are colloidal. To understand the real meaning of the term colloidal it is necessary to know something of the nature of a solution. When a substance, such as sugar, goes into solution in a solvent, such as water, the sugar is split up into its ultimate particles (molecules)—smaller particles than these cannot exist as sugar—and these particles will distribute themselves amongst the particles (molecules) of water in such a way that any sample of the solution contains the same proportions of sugar and water. It is quite impossible, with the most powerful microscope known, to distinguish the particles either of sugar or water, and quite impossible to separate the two by any mechanical means. If the original masses of sugar were not divided up into molecules, but were present as sufficiently large particles, than these particles could be seen. At the same time, masses of sugar of such a size would tend to sink towards the bottom of the vessel containing the water, and water and sugar could be separated mechanically. Actually, in making such a solution, one sees the larger particles sink towards the bottom of the vessel and then gradually go into solution, and, given sufficient time, the sugar becomes evenly dispersed throughout the water. In a true solution, the particles are, at the largest, molecular. If we take a piece of metallic gold, immerse it in water, and divide it up into smaller and smaller parts, it is obvious that in the end, supposing that our powers of manipulation were adequate, that we should arrive at the molecular condition. But, before this state is reached, we should have passed through a state in which the particles were so fine as to be invisible, as such, by ordinary means of illumination; and they would remain in permanent suspension, so as to simulate very closely a true solution, in which the substance dissolved is in the molecular state. In the course of this process of division, the larger fragments of gold in the early stages sink at once, after being stirred up, but as smaller and smaller particles are formed, the time taken to fall becomes longer and longer, until, when less than a certain size, they do not appear to sink at all. They are now in what is called the "colloidal state". Their dimensions at this stage are enormously greater than those of molecules of gold

but it is clear that we can draw no definite line of demarcation between the visible and the solid lump, from which we started, the colloidal state and the final molecular state. A colloidal state is one in which at least two phases exist, *e.g.*, gold and water. In a true solution, all the substances are in a similar state of molecular dispersion. The colloidal condition is unstable. "The colloidal is, in fact, a dynamical state of matter." It possesses energy, and the energy is associated (as we know energy always is associated) with the definite surfaces which separate one state of matter from another. The colloidal condition is probably the primary source of the phenomena of life. In the example of gold and water, the water is regarded as the continuous phase and the gold as the dispersed phase, *i.e.*, we may regard the water as a continuous state of matter surrounding small particles of gold (in a different state of matter). It is apparent that, theoretically at least, the reverse consideration should hold, where particles of water are dispersed in a continuous phase of gold. Moreover, the two phases are only a matter of degree and not of kind, for the dispersed phase could be made to merge imperceptibly into the continuous, and *vice-versa*. In the examples considered above, the colloid has been regarded as composed of a solid dispersed as small particles in a liquid (or *vice-versa*). This is the condition most commonly met with in plant cells, but gases, liquids or solids may exist in the colloidal state within each other. The following examples (taken mainly from Bayliss) illustrate such of these colloidal states of matter as are commonly met with.

Internal or Dispersed Phase	External or Continuous Phase	Example
1. Gas	Liquid ...	Foam
2. Liquid	Gas	Fog
3. ,, *e.g.* Kerosene ...	Another immicible liquid *e.g.* water ...	Emulsion (Kerosene spray)
4. ,, ...	Solid	Jelly
5. Solid	Gas	Tobacco smoke
6. ,, ...	Liquid	Colloidal solution of gold. Some forms of copper for spraying
7. ,, ...	Another solid ...	Ruby glass

Most of the physical properties of cells are directly due to their colloidal nature. The subject is, however, far too complicated to be gone into here. The colloidal nature of the cells must, to some extent, govern the loss of water by a withering leaf. The protoplasm is initially in a watery condition, but, as more and more water is lost, the very nature of the protoplasm makes water loss increasingly difficult.

Many important properties of the cell depend on the properties of substances in solution. Gases exert a definite and easily measurable pressure (due to the continual movement of the gas molecules). Substances in solution exert an exactly similar pressure in the solvent (due to the continual motion of the molecules in solution). If a solution of, say, cane sugar, is separated from a mass of pure water by a membrane or skin of such a nature that the membrane is perfectly permeable to both water and the sugar molecules in solution, then the water and sugar molecules will adjust themselves so that the sugar (and the pressure due to the sugar) is evenly distributed throughout the water on both sides of the membrane. If, however, the membrane is not permeable to sugar but is permeable only to water, *i.e.*, can be traversed by water molecules but not by sugar molecules, then the pure water will pass through the membrane into the sugar and water solution. This passage of water may be regarded as an attempt to equalise the sugar concentration (and, consequently, the pressures) on both sides of the membrane, and water will flow into the sugar solution until the latter is infinitely diluted, *i.e.*, until the percentage of sugar becomes quite negligible. Such an apparatus as that shown in Fig. III may be used to demonstrate the process : water from A passes through the membrane and causes a rise of the solution in the tube. Such a passage of water through a membrane to a solution on the other side of the membrane, is known as osmosis. Osmosis depends on the presence of a membrane which is permeable to one substance, such as the solvent, but is impermeable (or relatively so) to another substance in solution (solute). Such a membrane is said to be semi-permeable, as contrasted with a completely permeable

membrane. The nature of many such membranes is affected by the substances with which they are in contact, so that a membrane may alter its properties with changing conditions in the solution. The study of permeability is a study of changes in the relative permeability to different substances of a membrane which is not completely permeable, *i.e.*, changes in the properties of a semi-permeable membrane. The protoplasm of the plant cell acts as a semi-permeable membrane between the solution in the vacuoles and any external solution, such as the soil water. Water, therefore, passes into the cell, which increases in volume. The cell, however, is surrounded by a resistant wall, and a state of turgor is set up, which accounts for much of the rigidity of the plant structure. Loss of water, as in withering, means a loss of rigidity. In an exactly similar way, if the tube illustrated in Fig. III was sealed at the top, great pressure would be set up inside. If the tube was replaced by an extensible and semi-permeable bladder, the bladder would increase in size. The osmotic flow of water plays a considerable part in the life of the plant. Water must enter the root by this means, and the bleeding of many plants in spring, such as may be seen by cutting through the stem at ground level, is due mainly to an osmotic flow of water. Many leaves exude small drops of water from the leaf serrations (the Mycologist informs me that tea leaves show this phenomenon). This again is an osmotic process. Very marked osmotic activity is to be seen in certain large cells of the banana leaf and leaf stalk. When the plant is cut down after fruiting, copious bleeding occurs. The flow of water in osmosis is from a region of low concentration to a region of high concentration. Thus, the water surrounding the tube and membrane in Fig III could have been replaced by a sugar solution more dilute than that in the tube, and the flow of water would still have been in the same direction as previously. If, however, the external sugar solution had been more concentrated than that in the tube, then water would have flowed out of the tube and into the surrounding vessel. The osmotic properties of a solution depend, not so much on the chemical nature of the substances in solution, as on their behaviour in the solution. If a mixture of substances is present in solution, and the membrane

(as in Fig. III) is permeable to one of the substances, then the latter will not necessarily be drawn passively through the membrane with the flow of water, but the passage of that substance will be governed by its relative concentration on each side of the membrane. The protoplasm of the cell acts as a semi-permeable membrane which offers great resistance to the passage of sugars, simple proteins and tannins. Consequently, these are retained within the cell vacuoles. A considerable amount of resistance is also offered to the flow of simple substances such as sulphates, nitrates, chlorides and phosphates, so that the cell holds on very firmly to its absorbed food material. Yet, if this was always the case, the cell could not take in food materials. The permeability of the protoplasmic membrane—different for different substances —varies with the nature and concentration of the substances on each side of it. Thus the properties of the membrance are not fixed, but are continually changing with the changing chemical processes in the living cell, and the permeability is, morever, influenced by conditions outside the cell. The protoplasmic membrane, in effect at least, functions as a self regulating membrane. One can say that, in general, the membranes of cells such as those of a plucked leaf, are impermeable to colloids (including tannins) and to the majority of the simple inorganic substances in the cell sap. One of the great objects of manufacture is to cause the leaf cells to release their contained tannins, and it is very probable that conditions leading to an alteration in the permeability of the protoplasm, play just as great a part as any mechanical process to which the leaf is subjected.

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